(, For Restricted Circulation Only)

FOURTH COURSE

ON

SOLID WASTE MANAGEMENT AND ENVIRONMENTAL CLEANLINESS

(MAY 4 - 8, 1987)

COURSE DIRECTOR
RAKESH GUPTA

INDIAN INSTITUTE OF PUBLIC ADMINISTRATION
(CENTRE FOR URBAN STUDIES)
INDRAPRASTHA ESTATE, RING ROAD NEW DELHI-110002

MAY 1987.

CONTENTS

....

A GLOSSARY OF SOLID WASTES MANAGEMENT

Agricultural Solid Wastes: Wastes produced from the raising of plants and animals for food, including manure, plant stalks, hulls, and leaves.

Ash: The incombustible material that remains aftef a fuel or solid waste has been burned.

At-Site Time: The time spent unloading and waiting to unload the contents of a collection vehicles or loaded container at a transfer station, processing facility, or disposal site.

Bacteria: Single-cell, microscopic organisms with rigid cell walls. They may be aerobic, anaerobic, or facultative; they can cause disease; and some are important in the stabilization and conversion of solid wastes.

Biodeer-cable: A compound that can be degraded or converted to similar compounds by microroganisms.

Bulky Waste: Large wastes such as applicances. furniture, some automobile parts, trees and branches, palm fronds, and stumps.

Carbonaceous Matter: Pure carbon or carbon compounds present in solid wastes.

Carbon Dioxide (CO_2): A colorless, ordorless, nonpoisonous gas that forms carbonic acid when disssolved in water. It is produced during the thermal degradation and microbial decomposition of solid wastes.

Carbon Monoxide (CO): A colorless poisonous gas that has an exceedingly faint metallic odor and taste. It is produced during the thermal degradation and microbial decomposition of solid wastes when the oxygen supply is limited.

Collection: The act of picking up wastes at homes, business, commercial and industrial plants, and other locations, loading them into a collection vehicle (usually enclosed), and hauling them to a facility for transfer or further processing or to a disposal site.

Collection Routes: The established routes followed in the collection of wastes from homes, business, commercial and industrial plants, and other locations.

Collection Systems: Collectors and equipment used for the collection of solid wastes, solid waste collection systems may be classified from several points of view, such as the mode of operation, the equipment used, and the types of wastes collected. In this text, collection systems have been classified according to their mode of operation into two categories: hauled container systems and stationary container systems.

Combustibles: Various materials in the waste stream that are burnable. In general, they are organic in nature-paper, plastics, wood, and food wastes.

Combustion: The chemical combining of oxygen with a substance that results in the production of heat and usually light.

Commercial Solid Wastes: Wastes that originate in wholesale, retail or service establishments, such as office buildings, stores, markets, theatres, hotels, and warehouses.

Compactor: Any power-driven mechanical equipment designed to compress and thereby reduce the volume of wastes.

Compactor Collection Vehicle: A large vehicle with an enclosed body having special power-driven equipment for loading, compressing, and distributing wastes within the body.

Component Separation: The arranging or sorting of wastes into components or classes.

Compost: A mixture of organic wastes partially decomposed by aerobic bacteria to an intermediate state. It can be used as a sail conditioner.

Construction Wastes: Wastes produced in the course of construction of homes, office buildings, dams, industrial plants, schools, etc. The materials usually include used lumber, miscellaneous metal parts, packaging materials, cans, boxes, wire, excess sheet metal, etc.

Container: A receptable used for the storage of solid wastes until they are collected.

Conversion: The transformation of wastes into other forms. Transformation by burning or pyrolysis into steam, gas, or oil are examples.

Conversion Products: Products derived from the conversion of solid wastes, such as heat from combustion and gas from biological conversion.

Conver Material: Soil used to cover compacted solid wastes in a sanitary landfill.

Decomposition: The breakdown of organic wastes by bacterial, chemical, or thermal means. Complete chemical oxidation leaves only carbon dioxide, water and inorganic solids.

Demolition Wastes: Wastes produced from the destruction of buildings, roads, sidewalks, etc. These wastes usually include large, broken pieces of concrete, pipe, radiators, duct work, electrical wire, broken-up plaster walls, lighting fixtures, bricks, and glass.

Dewatering: The removal of water from solid wastes and aludges by various thermal and mechanical means.

Digestion: The biological conversion of processed organic wastes to methane and carbon dioxide under anaerobic conditions.

Disposal: The activities associated with the long-term handling of (1) solid wastes that are collected and of no further use and (2) the residual matter after solid wastes have been processed and the recovery of conversion products ore engrge has been accomplished. Normally disposal is accomplished by mens of sanitary landfilling.

Effluent: Any solid, liquid, or gas that enters the environment as a by product of humanactivities.

Energy Recovery: The process of recovering energy from the conversion products derived from solid wastes, such as the heat produced from the burning of solid wastes.

Ferrous Metals: Metals composed predominantly of iron. In the waste materials stream, these metals usually include cans, automobiles, refrigerators, stoves, etc.

Fly Ash: Small solid particles of ash and soot generated when coal, or wastes are burned. With proper equipment, fly ash is collected before it enters the atmosphere. Fly ash residue can be used for building materials (bricks) or in a sanitary landfill.

Food Wastes: Animal and vegetable wastes resulting from the handling, storage, sale, preparation, cooking, and serving of foods, commonly called garbage.

Front-End System: Those processes used for the recovery of materials from solid wastes and the preparation of individual components for subsequent conversion using rear-end systems.

Functional Element: The term functional element is used in this text to describe the various activities associated with the management of solid wastes from the point of generation to final disposal. In general, a functional element represents a physical activity. The six functional elem elements used throughout this bookare waste generation, onsit storage, collection, transfer and transport, processing and recovery and disposal.

Garbage (see Food Wastes)

Generation (See waste Corporation)

<u>Groundwater:</u> Water beneath the earth's surface and located between saturated soil and rock. It is the water that supplies wells and springs.

<u>Haul Distance:</u> The distance a collection vehicle travels (1) after picking up a loaded container (hauled container system) or from its last picking stop on a collection route (stationary container system) to the solid waste transfer station, processing facility, or sanitary landfill, and (2) the distance the collection vehicle travels after unloading to the location where the empty container is to be deposited or to the beginning of a new collection route.

<u>Haul Time:</u> The elapsed or cumulative time spent transporting solid wastes between two specific locations.

<u>Hauled Container System:</u> Collection systems in which the containers used for the storage of wastes are hauled to the disposal site, emptied, and returned to either their original location or some other location.

<u>Hazardous Wastes:</u> Wastes that by their nature are inherently dangerous to handle or dispose of. These wastes include radio-active substances, toxic chemicals, biological wastes, flammable wastes, and explosives. They usually are produced in industrial operations or in institutions.

Hog Feeding: Disposing of food wastes by feeding them to hogs. State regulations usually require that the wastes be cooked to kill bacteria feeding. Some states have regulations making hog feeding of food wastes illegal.

Hydrogen Sulfied (H_2S): A poisonous gas with the odor of rotten eggs that is produced from the reduction of sulphates in, and the putrefaction of, a sulfur-containing organic material.

Incineration: The controlled process by which solid, liquid, or gaseous combustible wastes are burned and changed into gases, and the residue produced contains little or no combustible material.

Industrial Wastes: Wastes generally discarded from industrial operations or derived from manufacturing processes. A distinction should be made between scrap (these materials which can be recycled at a profit) and solid wasted (those that are beyond the reach of economic reclamation).

Leachate: Liquid containing decomposed wastes, bacteria, and other materials and drains out of landfills.

Litter: That highly visible portion of solid wastes that is generated by the consumer and carelessly discarded outside the regular disposal system. Litter accounts for only about 2 percent of the total solid waste volume.

Manual Separation: The separation of wastes by hand. Sometimes called "hand-picking" or "hand sorting", manual separation is done in the home or office by keeping food wastes separate form newspaper, or in a revonery plant by picking out large cardboard or metal objects

Materials Balance: An accounting of the weights of materials entering and leaving a processing unit, such as an incinerator, usually on an hourly basis.

Materials Recovery (see Resource Recovery)

Mechanical Separation: The separation of wastes into various components by mechanical means.

Methane (CH_4) An odorless, colorless, and asphyxiating gas that can explode under certain cirumstances and that can be produced by solid wastes undergoing aerobic decomposition.

Microorganisms: Generally, any living thing microscopic in the size and including bacteria, yeasts, simple fungi, some algae, slime molds, and protozoans. They are involved in stabilization of wastes (composting) and in sewage treatment processes.

Moisture Content: The weight loss (expressed in percent) when a simple of solid wastes is dried to a constant weight at a termperature of 100^0 to 150^0 C.

Municipal Wastes: The combined residential and commercial wastes generated in a given municipal area. The collection and disposal of these wastes are usually the responsibility of local government.

Nonfarious Metals: Metals that contain no iron. In wastes these are usually aluminium, copper wire, brass, bronze, etc.

Off-Route Time: All time spent by the collectors on activities that are nonproductive from the point of view of the overall collection operation.

Onsite Handling, Storage, and Processing: The activities associated with the handling, storage, and processing of solid wastes at the source of generation before they are collected.

Organic Materials: Chemical Compounds of carbon combined with other chemical elements and generally manufactured in the life processes of plants and animals. Most organic compounds are a source of feed for bacteria and are usually cobustible.

Pick Time: For a haulod container system, it represents the time spent driving to a loaded container after an empty container has been deposited, plus the time spent picking up the loaded container and the time required to redeposit the container after its contents have been emptied. For a stationary container system, it refers to the time spent loading the collection vehicle, beginning with the stopping of the vehicle prior to loading the contents of the first container and ending when the contents of the last container to be emptied have been loaded.

Pollution: The contamination of soil, water, or the atmosphere by the discharge of wastes or otheroffensive materials.

Primary Materials: Virgin or new materials used for manufacturing basic products. Examples include wood pulp, iron ore, and silica sand.

Processing: Any method, system, or other means designated to change physical form or chemical content of solid wastes.

Pyrolysis: A way of breaking down burnable waste by combustion in the absence of air. High heat is usually applied to bewastes in a closed chamber, and all moisture everaporates and materials break down into various hydrocarbon gases and caronlike residue.

Rear-End System: Those chemical, thermal and biological systems and related ancillary facilities used for the conversion of processed solid wastes into various products.

Reclamation: The restoration to a better or more useful state, such as land reclamation by sanitary landfilling, or the extraction of useful materials from solid wastes.

Recoverable Resources: Materials that still have useful physical or chemical properties after serving a specific purpose and can therefore be refused or recylad for the same or other purposes.

Recovery (see Resource Recovery)

Recycling: Separating a given waste material (e.g., glass) from the waste stroam and processing it so that it may be used again as a useful material for products which may or may not be similar to the original.

Refuse: A term often used interchangeably with the term solid wastes. To avoid confusion, the term refuse is not used in this text.

Residential Wastes: Wastes generated in houses and apartments, including paper, cardboard, beverage and food cans, plastics, food wastes, glass containers, and garden wastes.

Residue: The solid materials remaining after cmpletion of a chemical or physical process, suchas burning, evaporation, distillation, or filtration.

Resource Recovery: Resource recovery is a general term used to describe the extraction of economically usable materials or energy from wastes. The concept may involve recycling or conversion into different and sometimes unrelated uses.

Reuse: The use of a waste material or product more than once.

Rubbish: A general term for solid wastes - excluding food wastes and ashes - taken from residences, commercial establishments, and institutions.

Sanitary Landfill: A land area where solid wastes are disposed of using sanitary landfilling techniques.

Sanitary Landfilling: An engineered method of disposing of solid wastes on land in a manner that protects the environment, by spreading the wastes in thin layers, compacting it to the smallest practical volume and convering it with the soil by the end of each working day.

Secondary Material: A material that is used in place of a primary or raw material in manufacturing a product.

Separation: To divide wastes into groups of similar materials, such as paper products, glass, food wastes, and metals. Also used to describe the further sorting of materials into more specific categories, such as clear glass and dark glass. Separation may be done manually or mechanically with specialized equipment.

Service Site or Location: A residential unit, business, commercial or industrial establishment, or other pick-up point from which solid wastes are collected periodically.

Shredding: Mechanical operations used to refuce the size of solid wastes. See also Size Reduction (Mechanical).

Size Reduction (Mechanical): The mechanical conversion of solid wastes into small pieces. In practice, the terms shredding, grinding, and milling used interchangeably to describe mechanical size-reduction operations.

Solid Wastes: Any of a wide variety of solid materials, as well as some liquids in containers, which are discarded or rejected as being spent, useless, worthless, or in excess. Does not usually include waste solids from treatment facilities. See also agricultural, commercial, construction, demalition, bazardous, industrial, municipal and residential wastes.

Stationary Container Systems: Collection systems, in which the containers used for the storage of wastes remain at the point of waste generation, except for occasional short trips to the collection vehicle.

[illegible]

<u>Transfer:</u> The act of transferring wastes from the collection vehicle to larger transport vehicles.

<u>Transfer Station:</u> A place or facility where wastes are transferred from smaller collection vehicles (e.g. compactor trucks) into larger transport vehicles (e.g. every the road and off-road tractor trailers, railroad gondole cars, or barges) for movement to disposal areas, usually landfills. In some transfer operations, compaction or separation may do not at the station.

<u>Transport:</u> The transport of solid wastes transferred from collection vehicles to a facility or disposal site for further processing or action.

<u>Trash:</u> Wastes that usually do not include food wastes but may include otherorganic materials, such as plant trimmings.

<u>Treatment process sludges:</u> Liquid and emisolid wastes resulting from the treatment of domettic waste water and industrial wastes.

<u>Virgin Material:</u> Any basic material for industrial processes which has not previcously been used, for example, wood-pulp trees, iron ore. silica sand, crude oil, bauxite, See also Secondary Material, Primary Materials.

<u>Volume Reduction:</u> The processing of wastes so as to decrease the amount of space they occupy. Complete conventional incineration can raduce volume by 90 per cent; high-temperature incineration can reduce volume by as much as 98 per cent. Compaction systems can also reduce volume by 50 to 80 per cent.

Waste Generation: The act or process of generating solid wastes.

Waste Sources: Agricultural, residential, commercial, and industrial activities, open areas, and treatment plants where solid wastes are generated.

Waste Stream: The waste output of an area, location, or facility.

Management of Urban Solid Wastes

By G.N. Gosh

In India, during the post-independence era there is rapid industrialisation in and around large cities. Lack of job opportunites in rural areas has led to fast urbanisation. One of the major ill-effects of this situation is unabated rise in solid, liquid and gaseous pollution causing serious health hazards. Greed, lack of education and foresight, unworkable laws, inefficiency, corruption and apathy are the major causes for this appalling situation.

Urban solid wastes includes domestic, market, hospital, human, and clandestinely dumped construction rubbish and industrial wastes. Its primary and secondary ill-effects on health occur in various subtle forms and as such do not receive much public attendion. Efficient management of urban solids involves difficult technological and micro-biological problems. Further, the subject being non-glamorous has not attracted involvement of senior and creative engineers. Grinding poverty has compelled men and women to sifting of garbages, a very unhealthy means of livelihood, for retrieving papers, pastics, metals glass and other materials for their very survival.

Various facets of urban waste and inter-disciplinary subjects have been studied and surveyed in depth by three senior engineers and a lawyer for about three years. Thorough studies have been carried out in Bombay, Calcutta, Jameshedpur, Delhi and Kalyan municipal corporations by visiting markets, hoppitals, schools, public places, etc.,

and meeting relevant persons who are directly involved in their respective work. Also some visits and studies have been made about this subject as practiced in Western and other progressive countries. These efforts have resuted in the design, field-trial and manufacture of multi-advantageous garbage containers uniquely suited for Indian conditions.

Wherever a living being stays or visits, wastes in various forms are produced. Rural and urban areas, and even areas surrounding Mount Everest are littered with wastes. With community living and passage of time, the waste problem gets aggrawated. The wisdom lies in adopting an effective method in which wastes are controlled and are put to economic use causing minimum imbalance in nature and contributing maximum benefit to the inhabitants.

In the very early days of human civilisation as far back as 2500 B.C. in the towns of Assyria and Babylon, Harappa and Mohenjodaro, considerable attention was paid towards the problems of waste disposal. Early Romans constructed sewers to carry wastes. About 1700 B.C. Hammurabai, a Babylonian king set up laws that governed health and family life. It is said that in Roman towns there used to be prominatly displayed signboards waring; "Take your refuse further or you will be fined". In Indian sub-continent a highly sophisticated system of drainage could be found in Harappa and Nalanda, dating back to 2500 B.C.

Later, littering of food and other solid wastes in medieval European towns and the practice of throwing refuse on the unpaved streets, roadways and vacant lands led to the breeding of rats and flies carrying germs of disease which caused the outbreak of plague. The lack of management of solid wastes led to the outbreak of plague that killed half of the European in the fourteenth century and cuased many subsequent epidemics resulting in a large number of death.

It was not until the nineteenth century that health control measures became a vital consideration to public officials, who realised that food wastes had to be collected and disposed off in a sanitary manner to control the vectors of diseases. The period around 1900 has been called the era of the "Great Sanitary Awakening". It wasthen that the factors causing the great epidemics and high incidence of enteric diseases were shown to be caused by micro-organisms, and a crakdown on sewage disposal problems began.

In Bombay, between 1896 and 1899 when the population was 8 lakhs, 1,14,000 people dies of plague and 43,000 left the city. Uncollected garbage provided the forage for the gluttonous and ferocious rats which are the carriers of plague.

The census of 1981 shows Indian urban population as 162 million as against 120 million in 1971. It is expected to cross 200 million by 1991. As surveyed by the National Environmental Engineering Research Institute, Nagpur , the total refuse generated in 174 class I cities (whose

population is over 1,00,000) alone is 32,450 tonnes per day which is expected to reach more than 60,000 tonnes per day in the year 1991. The largest seven of the 12 metropolitan cities Calcutta, Bombay, Delhi, Madras, Bangalore, Hyderabad and Ahmedabad alone contribute 18,000 tonnes of refuse per day i.e. 2,570 tonnes per day per city on average. Twenty-five cities with population between 5 and 20 lakhs generate 7,370 tonnes per day averaging 295 tonnes per day. Indian urban population exceeds the combined total urban population of Canada, France and Japan. These figures show the magnitude of the waste generation and it calls for their efficient management. Although waste generated per capita by 700 million Indians is much less than over 1 tonne waste produced per person per year by 200 million in the United States, the various aspects of wastes are managed well in the United States.

Rapid Urbanisation: With rapid migration of rural masses to urban areas, particularly in developing countries, pollutants in the form of solid, liquid and gaseous wastes are being produced at an ever increasing rate. This process will continue in the foreseeable future. More often the civic authorities are not able to cope up with the increasing loads due to corruption, low efficiency, illegal and unethical political pressures, improper use of technology and paucity of funds. In this situation, in their own interest, the people must become more responsive and fulfil their duty and practise restraints and force authorities to discharge their part of obligation.

Solid Wastes: As defined by the World Health Organisation, the term "solid waste" is applied to unwanted and discarded materials from houses, street sweepings, commercial and agricultural operations arising out of mass activities. It is a mixture of vegetable and non-vegetable wastes in cooked and uncooked stages, leftovers, packaging of different kinds, papers, plastics, rags and other fabrics dust, ash and a variety of combustible and non-combustible, bio-degradable and non-biodegradable matter. These materials are commonly known as garbage or trash. Solid wastes also include tree cuttings and garden refuse but do not include construction debris from building or road work. Indian municipalities follow this definition of the world Health Organisation of solid wastes, which, excludes the trade and industrial wastes that contain a variety of materials that could even be toxic and hazardous.

Solid wastes are probably the most visible form of pollutants. They present a serious problem because most of the methods used to dispose them result in some type of damage to the environment. Open dumping is ugly and offers home for disease carrying insects and animals. Its burning pollutes air and its random dumping in water affects aquatic life and the subsequent use of water.

Of all forms of wastes, solid wastes pose the most difficult technological problems due to their widely varying constituents, size and physical properties. The minimum angle of inclination (slope) at which wolid waste start flowing by gravity is called the angle

of repose" and it plays a vital part in solid handling. Since this factor is not well undestood by engineers, it results in poor design of receptacles and conveying systems. Liquid and gases are handled through closed vessels or conveying systems either with adequate slope or by application of pressure and the system works efficiently. The urban solid wastes, particularly those generated under Indian conditions do not follow simple law of fluids. They do not contain profitable raw materials and the subject being not glamorous, that is the study of garbage handling, though very important for the society, has not attracted sustained attention of senior engineers.

Categories of Urban Wastes: The wide variety of discarded materials fall into the following categories:

1. Domestic refuse: Pustriscible kitchen and food wastes, plastics, papers, scantlings and floor sweepings.

2. Market refuse: Mostly putriscible vegetable, animal and fish matters; packaging materials and consisting of timber boxes.

3. Hospital refuse: Wastes from wards, cabins, pantries, operation theatre wastes, needles, ampules, bottles, ampulated limbs, cotton, gauzes, plaster, and food wastes.

4. Road Sweeping: Leaves, scantlings, animal droppings, human waste and a variety of litter, mostly dust.

5. Garden refuse: Leaves , branches, plants, broken pots, stones.

6. Business area wastes: Various type of paper, cigarette and bdid butts, matchsticks, fruit peelings, leaves and paper plates bus tickets, carbon paper, telex papertapes, tailoring and carpentary work wastes.

7. Cattle shed and stable refuse: Animal wastes and general litter.

8. Trade refuse: Cloth cuttings from tailoring shops, car repairing garages.

9. Road construction rubbish: Earth, asphalt, concrete, dust, wood glass, stones.

10. Building construction rubbish: Earth, concrete, brick, plaster etc.

11. Industrial wastes: Oil soaked rags, themoplastic wastes, timber scantlings, chemical refuse including toxic matter.

Wastes from any particular geographical area under each of the above category have their own characteristics. They are mostly wet and contain a high percentage of dust and ash.

Excreta and urine post severe health hazards and require a different way of handling. Therefore, it has not been covered in this article. It is out intention to present a seperate set of articles, later, due to the enormity of the problem.

The solid waste problems of the metropolitan cities of Bombay , Calcutta, Delhi and Jameshedpur have been studied. The situation in Bombay has been studied in greater detail with a conviction that if any solution can be evolved for this city, the same can be applied to other cities with little change.

Per capita generation of solid wastes under category 1 to 8 stated earlier, i.e. all solid wastes excluding road and building construction debris and industrial wastes, in Bombay and Calcutta is 400 to 500 grams a day, while cities like Pune and Nagpur produce about 300 grams. Exclusively, the average per capita garbage produce in kitchens including food wastes is about 200 grams a day and occupies about 300 millititres when kept in tight plastic bags and occupies almost double the space when kept in loose farm. Affluent areas produce about three times wastes per capita, compared with poorer areas.

Table 1 shows the quantity of wastes produced by the population in Bombay during the years 1931, 1971 and 1981 and the projections for 2000 A.D.

Table 11 compares the quantities of waste the, cost per capita cost of handling a tonne of waste and the sweepers employed in the years 1974 to 1984.

These figures relate to the Greater Bombay Municipal Corporation. The calorific value of refuse at dumping grounds varies between 1100 kcal to 400 kcal per kilogram but is generally less than 2000 kcal per kilogram.

Table 1: Year, population and wastes produced in Bombay:

1931 - 12 lakhs, 1040 tonnes; 1971 - 60 lakhs, 2500 tonnes:

1981 - 83 lakhs, 3000 tonnes; 2000 - 191 lakhs, 8200 tonnes (PROJECTED)

As there was no substantial increase in either the road mileage or area of the city from 1974 to 1984 figures in Table 11 shows that there is sufficient scope for cost reduction and for providing better civic services.

In 1981 with 13 lakh of people in Bombay, the daily generation of garbage was 1040 tonnes from houses and public places and during that period 30,000 community garbage bins were in use and these were emptied daily.

<u>Market Refuse:</u> Greater Bombay has over 70 major wholesale and retail vegetable, meat, fish and fruit markets. A detailed study of seven major markets of South, Central and North Bombay was made. Methods of waste generation and of waste handling were similar everywhere. Markets are strewn with vegatable leaves, straw and leaves used as packagings and these often reach a putrification stage in the shopping areas. Sweepers collect these at intervals in large basket and dump into usually broken masonary cubicles which are maintained poorly and emit an awful stench. These are again filled into baskets and loaded into the trucks for final disposal. It is while filling these trucks, the surrounding areas are surcharged with a nauseating smell. In North Bombay a new multi-storeyed market in the place of old one has been constructed, but garbage dumping cubicle remains in the same dilapidated condition, and dogs and cows are found inside the cubicle and nearby shops and passersby suffer from the stench. The wastes are collected once or twice a day.

There remains much scope for cleanliness and installation of a large size metal bin of proper design that is elavated and enclosed and which could directly fill the truck and will considerably eliminate the stench is needed. This will help to keep the area clean and make the truck filling operation far more quick, thereby reducing the detention time of the trucks and their cost of haulage. If these are covered trucks, the stench can be eliminated almost completely.

<u>Hospital Refuse:</u> The problems relating to generation and handling of wastes were studied extensively in eleven major hospitals that were run by government, municipality or privately. In Bombay, Calcutta, Delhi and Jameshedpur, the relevant matters were discussed with doctors, nurses, maintenance officers, kitchen managers, sanitary inspectors and sweepers. There was discontent among all concerned about the method used for the storage of wastes and their removal. The wastes emanating from wards, kitchens and operations theatres are dumped in buckets and tubs that are mostly open. These are carried by handcarts or on shoulder and emptied in masonary cubicles which are located normally in close proximity of the main entrance of the hospital.

Some hospitals dumps their fefuse in and around public masonary cubicle and smaller metal bins by the side or public roads. All dumping places attract crows, dogs, rodents and rag-pickers. These storage dumps emit an extremely nauseating stench and unhealthy sights. The hospital wastes are especially hazardous due to large

Table- II

Comparative costs of waste management in Bombay.

Year	Population	Garbage produced per day (tonnes)	No. of Sweepers	Cost of waste management per year	Cost of waste management per tonne	Cost per Capita per year	Refuse pro duced per capita pe day.
1934	14 lakhs	1100	6000	-	-	-	800 gms.
1974	62 lakhs	2250	7000	Rs. 5 Cr.	Rs. 61	Rs. 8	360 gms.
1984	86 lakhs	3200	2000	Rs.23 Cr.	Rs. 198	Rs. 27	376 gms.
Increase from 1974 to 1984	39 p.c.	42 p.c.	285 p.c.	460 p.c.	325 p.c.	338 p.c.	5 p.c.

concentration of pathogens, injection needles and the wastes from the operation theatre. Except for a few of the major limbs which are burnt in the well advertised incinerator, the rest are dumped along with other wastes. There have been reports that human placentas and ampulated arms have been found in garbage in Delhi. On the whole, the solid waste problem in hospitals are grossly neglected.

An improved version of portable garbage bins of easily opening and closing type and installation of an elevated large bin which could directly discharge into the trucks will alleviate the problem. As sweepers have to walk a long distance with the refuse containers on their shoulders, it will be worthwhile to have intermediate collection points where the refuse from wards and pantries can be dumped for further disposal to the large bins. The hospital refuse must be transported and dumped separately under hygienic conditions.

In contrast, it was a pleasant sight to go around the medical centre in Houston, Texas, U.S.A., where several hospitals are located, including the hospital where world renowned Dr. Denton Cooley performs the heart surgery. Let us improve upon our methods of the collection and disposal of wastes from hospitals. Comparing of the the technicality and high cost of constructio and running of hospitals, it is neither too difficult nor too expensive to achieve this, if needed in graduated steps, in India.

Office Areas: During the post-lunch period and in the evening when there is extensive littering, the refuse problems in busiest office areas of Bombay and Calcutta were studied. Primarily four types of littered materials were found.

1. Remnants of fruits and vegetables e.g. banana, orange, onion. potato peelings, empty shells of tender coconuts and their cuttings and the restaurant garbage. There are normally trown in baskets kept causally and perfunctiorily by the vendors. The hotel owners and vendors engage urchins to throw them into the municipal dumping cubicles which are infested with pests and animals.

2. Paper and leaves used as plates for serving the eatable by the roadside vendors, cigarette and beedi tips etc.

3. Floor sweepings which contain mostly paper, small and large and rolls of carbon papers.

4. Timber scantlings from machinery packagings and shavings from carpentry work.

Those litters keep on spreading due to the passing cars and the wind. Sho-keepers have repeatedly told us that due to open garbages, the gutters get choked often causing overflow of filthy water. Some of the areas are extremely unhygienic.

Though the municipal sweepers keep on working at regular beats, the continuous throwing of garbages makes it impossible to keep the places clean. With the installation of garbage bins of improved design at

convenient places, their upkeep and regular clearing of garbage by by civic authorities and by continual education of the public, this problem can be reduced considerably.

<u>Railway Station:</u> In Bombay over thirty lakh people travel by local trains daily of whom a vast majority board and alight at Churchgate, or Marine Line stations on the Western Railway and Victoria Terminus and Masjid stations on the Central Railway.

Spitting, littering and urinating are three major evils found platforms and filling their discarded bamboo fruit basket with litter. Most of the suburban stations do not have any dust bins , although there exist several prominetly displayed sign boards asking passengers to use dust bins. In major stations, large baskets like the dust bins are provided which are inadequate. About two years ago a number of floor-mounted small swivellin dust bins were provided. Unfortunately, those were found out as an obstruction to the traffic at rush hours and were mostly used as spitoons. Column mounted swivellin dust bins were also provided and were found to be more effective.

To combat this litterin problem, installation of a large number of properly designed wall-mounted bins is necessary. On the platforms of long distance trains and along the truck funning in densely populated areas one will experience smell of urine and human excreta. In Victoria Terminus and in the Dadar main station's railway platform, slum dwellers use the toilets of the wating train. Adequate facilities and constant

public education for proper use of railway platform and not throwing anything out of train compartments will keep both railway station its neighbouring area and track clean.

Scientific and efficient handling of all stages of solid refuse is called solid waste management. The problems associated with the management of solid wastes in today's society are complex because of the ever-increasing quantity and the diverse nature of wastes rapid development of urban areas and funding limitations. If solid waste management is to be accomplished in an efficient and orderly manner, the fundamental aspects and relationsips involved must be identified and understood clearly. Different stages through which Solid Wastes pass.

<u>Storage at source and carting:</u> The garbages from houses, markets, hospitals, schools, parks, railway stations, eating houses, hotels and road sides are stored in different receptacles. These wastes cannot be stored for long at individual place because of their bio-degradiability and putrescibility and they must be removed daily for Hisposal.

At most of these places normally, open buckets with lids are provided. These are not used as it requires operation by both hands. Some house-holds have tried buckets with foot-operated lids, but these do not work for long. These buckets are made either of polyethylene or galvanised iron. Polyethylene buckets break after some time and galvanised

buckets either rusts badly or gets stolen when used in public places. From individual small bins are refuse is dumped in a larger container often without a lid which is made of polyethylene that does not last long. These larger buckets are normally carried on shoulder by private sweepers and during that stage the surroundings get filled with nauseating smell and the contents are in the process of putrifaction mostly under anerobic conditions. Quite often these vessels are heavy. The load should not exceed twenty kilograms. Further, the flat base of these buckets hurts the shoulder.

<u>Community storage awaiting collection:</u> These are owned by the municipal corporation and are located in public places. These need serious attention as these are accessible to pests, rats, birds animals and rag-pickers. Our country being hot, putrifaction is very rapid. Some of the commonly used receptacles are made either of metal wire mesh or corrugated sheets with angles at corners or entirely made of thick steel plates. Top and base of these bins are usually open. In Bombay thick cylindrical steel bins with open top and bottom are commonly used. Usually three types of masonry receptacles are used. A three-sided open masonry enclosure, a three- sided covered enclosure or a large covered enclosure with one side fully open and one side having window type opening for dropping garbages. Typical receptacles presently in use suffer from the same serious defects in design, especially because garbages are thrown on the floor and remain exposed.

The bins being open, the areas surrounding the bins and cubicles become very filthy and smelly. The users do not like to go near enough to the bins and as a result, the refuse is dumped both inside and outside the bins or cubicle and the users keep on dumping refuse farther and farther away from the receptacle and in a short time the whole area gets badly littered. Due to poor maintenance, most of the cubicles and bins are in bad state,. Garbage is dumped during any time of the day and even at late hours at night. No sooner the garbage is dumped, rats, rodents, bandicoots, crows, hen cats, dogs, pigs, goats cows and also human beings feast there. Thereafter rag-pickers start their work. There are about 4000 such collecting points in Bombay. Contrary to their trade name, the rag-peikers do not pick up rags; they collect only large sized plastics, paper, glass and metal-pieces.

<u>Collection and transportation:</u> Lorries and tractors are used for refuse collection. In Bombay a ream of six motor loaders with a junior supervisor move in a vehicle with a driver and an assistant. The loaders empty the refuse from the metal bins on the ground and by using rakes they fill their baskets. The garbage from these baskets is dumped into the vehicles. Although under Indian conditions, municipalities are expected to collect refuse twice a day, the vehicles come only once a day or once in two days. During the lorry loading operating, the entire area is filled with stench. The system of tilting of bins and filling the baskets by raking over wide area is very unhygienic for the residents and the passer-by

and even one more so for the loaders who are exposed severely to these unhealthy conditions during their entire working life. In other cities open-top masonry cubicles of different designs are used all of which call for improvement.

Municipal garbage fleet in Bombay comprises vehicles which are of better design and have a steel body which can be cleaned easily. The large number of contract vehicles have wooden bodies which cannot be cleaned properly. Also twenty compactors are in use by they are very costly to purchase and maintain. The trucks are open at the back and all contract vehicles are open on the top as well. These are contrary to sanitary requirements. Sometimes, refuse on the trucks are covered with tarpaulins, a method which has some inherent defects. The vehicles need to be washed daily for sanitary reasons, a standard municipal practise which is hardly followed now. In Calcutta and Delhi dumpers with hydraulic tipping devices are used.

In certain areas of Jamshedpur, Calcutta and Delhi, Hydrocon Roll-on Tipple are used. In that system two large metal bins are used as roadside receptacles. When filled these bins one at a time are mechianically loaded over the chassis of a truck which is emptied by hydraulic tippiling system at dumping ground. These are expensive vehicles and particularly the hydraulic system is difficult to maintain.

House-to-house collection is by far the best method of collecting refuse. Under this system the refuse collector enter the premises and collects the refuse, thereby the householder is not involved in the

collection process. To be effective, the refuse bins in the premises must be of such design that the residents should not be inconvenienced by stench, ugly sight and health hazards. Unfortunately, neither municipalities, architects or builders have so far designed such a receptacle. Such a design now is available and with its help the house-to-house collection can be made effective, benefiting the municipality and the residents. Though storage of refuse is an inescapable function, it is seldom given adequate consideration by builders and designers. In the planning stage of homes and other buildings design consideration should be so as to minimise refuse handling within the building and to maximise the efficiency of the collection system. Littering is always associated with inadequate and poor storage practice.

The Environmental and Hygiene committee (1940) of the government of India has recommended that municipalities and other public bins but also from individual houses. Thus the central government has approved of house-to-house garbage collection system. House-to-house garbage collection, will result in a simultaneous redustion of public bins.

For the last four years, this system is in operation in two wards of Bombay and has met with partial success. In these wards, each new house has to build a refuse cubicle at a convenient place close to the entrance of the building compound as per municipal specifications. Being incongenially designed, these cubicles are not used. Those being

used have some inherent defects. Instead, refuse from the houses are either dumped into municipal trucks which stop at some points with the sounding of bells or in public dumping bins or clandestinely in front of someone else's house. The collection vehicle passes through a specified route and generally at a specific time which does not permit most of the residents to dump the garbage in the truck. Under this situation the dumping of garbage takes place either in the community bins or in the open. To make the working of house-to-house garbage collection successful even two or more houses (small) can jointly keep a communly bin in their premises by rotation.

This method of collection was thought of even in the thirites by the Bombay Municipality, and time and again it stressed that this system should be fully implemented. In the Western Cities except in the heart of cities this system is widely prevalent. Even in villages, people keep their garbage in plastic bags at roadside on specified places adjacent to the highways. On specific days of the week and at the appointed time, the bags are collected by the vans of respective local bodies.

A survey of World Bank has shown that people do not like to walk more than 50 metres for dumping refuse. The distance is to be greatly reduced for Bombay, considering the shocking state of our footpaths and ever-rising vehicular traffic on the roads. It is human nature to follow the path of least resistance and that is one of the factors that results in indiscriminate throwing of the refuse. On the contrary, if proper facilities are given first and afterwards the law

is the enforced strictly, the desired result will be achieved, just as it was done in Singapore to make it the cleanest city in the world.

There is no single method which is suitable in all situations. Depending upon the availability of land and its topography, economic viability, available technology and social conditions, any one or more of the following methods could be used: (1) open dumping (2) controlled tipping or sanitary land-fill; (3) incineration with the without power generation; (4) composting; (5) biogas generation.

Open dumping: Refuse is dumped in low lying areas partly as a method of reclamation of land but mainly as an easy method of disposal or dry refuse. As a result of bacterial action the refuse decreases considerably in volume and is gradually converted into humus. Except for a portion of Delhi in the recent past, all Indian cities including Bombay and Calcutta are using open dumping for well over 100 years. In Calcutta the reclaimed land is leased out for cultivation.

In Bombay there are five notified areas of low lying marshy creeks set aside for the purpose. These areas are Mahim-Sion creek at Dharavi, Deonar-Govandi creek adjacent to Chembur, Chincholi at Malad, Gorai at Borivli and Thana creek at Mulund and cover a total area of about 450 hectares. Construction debris are also dumped in these areas. The heaps of garbage and construction debris, if any, are levelled by bulldozers from time to time. The drawbacks of open dumping are:

(1) the refuse is exposed to flied and rodents, (2) it is a source of nuisance from smell and repulsive appearnance, (3) the loose refuse is disposed by the action of the wind and (4) serious pollution of surface and underground water.

A WHO Expert Committee (1967) condemned dumping as "a most insanitary method that creates public health hazards and severe pollution of the environment. Dumping should be outawed and replaced by sound procedures".

With fast expansion of class I cities, particularly metropolitan cities, new housing colonies are coming up close to the former dumping areas and particularly for this reason dumping should be discontinued in a phased manner.

<u>Controlled tipping or Sanitary land-fills.</u> Controlled tipping or sanitary land-fill is the most satisfactory method of refuse disposal where suitable land is available nearby. In this method the garbage is levelled in layers, compacted and covered with earth. Depending upon the condition of the site any one or more of following three methods are used: (1) the trench method: (It is chosen where level ground is available). (2) the ramp method: (for moderately sloping terrain this method is well suited). (3) the area method: (It is used for filling and depressions.

Bacteriological, chemical and physical changes occur in buried refuse, the temperature rises over 60 degree C within 7 days and kills all pathogens and hastens the decomposition process which requires 4 to 6 months. This method has been revolutionised by mechanical aeration.

The sanitary land-fill mthods was first tried in England in 1916, New York city and Fresno, Californaia experimented with the method in 1930. By the end of 1943 nearly one hundred cities and by 1959 more than 1400 cities in United States adopted this method.

Communities in the United States have been encouraged to use sanitary land-fills for the following reasons: (1) The equipment required to operate is relatively inexpensive and can be used for other municipal operations as well. (2) They reduce rodent breeding, a nuisance found around incinerators and in open dumps. (3) They avoid serious health threats represented by open burin or dumping. (4) They can be put into operation quickly . (5) They can be used to reclaim swamps, marshes and gulches.

The sanitary land-fill method of refuse dumping is suitable and adaptable under Indian conditions. Precisely located and fully operated land-fills may even enhance property values. The American Society of Civil Engineers has formulated the following definition of a sanitary land-fill. This also helps greately to distinguish from ordinary dumps being called "Sanitary land-fills".

"Sanitary land-filling is a method of disposing of refuse on land without creating nuisance or hazard to public health by utilizing the principles of engineering to confine the refuse to the smallest practical area, to reduce it to the lowest practical volume, and to cover it with a layer of earth at the conclusion of each day's operation or at such more frequent intervals as may be necessary".

Incineration: Refuse can be hygienically disposed off by buring or incineration. Though by this process 90 per cent volume reduction is possible it is capital and energy incentive and can cause severe air pollution. Majority of Indian garbage is too wet and contains excessive dust. In wet season, the refuse is almost drenched with water. Its low calorific value, which is generally less than 2000 kcal per kilogram of refuse, does not permit self-sustained buring in an incinerator. Only hospital refuse, which is particularly hazardous, is best dispoed by incineration. Incineration is widely practiced in Western countries in multistoreyed residential buildings, but there is wide criticism of these decentralised incinerators as a cause of air pollution. Since the refuse in West has a much higher calorific value, community incinerators function reasonably well and some of these even generate power. In Bombay four incinerators for buring human limbs, dead rats and highly contagious hospital wastes, are located at Haffkine Institute, J.J. group of Hospitals, a group of T.B. hospitals and at Worli.

Composting: Compost is a rich and balanced kind of humus; the fibrous part of the soil which is formed from the decompostible remains of plants and animals. In the natural state this decomposition process takes place slowly. Composting is one of the oldest methods of disposing of solid wastes known to man. For centuries farmers have been spreading human, animal and vegetable waste on the fields, returning organic matter to the soil. A working definition of refuse composting is the aerobic, thermophilic degradation of putriscible material in a refuse by micro-organism.

Windrow method of Composting: There are two methods of composting. One is the windrow method in which garbages are heaped in rows and mechanically turned over. This method is most economical in running expenses though it requires larger areas and 3 weeks for full composting. The Delhi Municipal Corporation is operating a Windrow Composting Plant of 150 tonnes per day capacity. The plant has been locally designed by engineers of Delhi Municipal Corporation. The entire area is very clean and there is hardly any stench or fly nuisance. The compost at the plant is used for the gardens of Delhi and the surplus is sold to farmers. It is heartening to know that the compost of the unit is fully booked. World's largest windrow compost plant is Netherland's VAM, or Waste Treatment Company, at Wijaster which receives about . million tonnes of refuse a year. Piled in long windrows, some of the refuses gradually decomposed in to compost. After inert items are separted,

the compost totalling approximately 1,25,000 tonnes a year is sold for farm and garden uses.

Mechanical composting: Mechanical compost plant enhances the bio-degradation process to such an extent that it is completed within 7 days or so compared with several weeks under open atmospheric conditions. In this process, the refuse is shreded and spread over a large area and air is blown through the mass for rapid aerobic decomposition or refuse converting the same into compost. The shredding machine is very capital-intensive and costly to maintain, as Indian garbage contains a high percentage of construction debris and other non-biodegradable refuse.

Bombay's Mechanical compost plant: In Bombay at Deonar, 300 tonne per day (16 hours) mechanical compost plant had been in operation. The cost of this project was initially Rs. 121 lakhs and on completion the cost went upto Rs. 149 lakhs. Production in 1982, was its peak 9,000 tonnes of compost. There are many design construction faults in the plant. Its production was hampered due to the presence of a large quantity of glass and ceramic pieces. Hypodermic needles were also found in refuse. Final product was not acceptable to the farmers due to presence of glass and ceramics. The functioning of the plant also suffered due to high input cost and high operational cost. There were technical problems, primarily due to the breakdown of rasping machine

for shredding, which and air supply system. It thefore been decided to shut down this plant from this year. It is particularly unfortunate that while the conventional synthetic fertilisers produced by modern capital intensive plants receive an annual subsidy of over Rs. 1,200 crores, the composted manure produced from garbage does not receive adequate support.

Pyrolysis: Technically pyrolysis is a destructive distillation, carried out at high temperature obtained with carbonisation, in the absence of air by the application of indirect heat; often the term thermal decomposition is applied.

Pyrolysis can convert dry wastes, cellulose and contaminated paper into usable fuels. With partial combustion, fuel gases can be produced.

In the past this process has been extensively used for the manufacture of acetic acid, methyl alcohol and turpentine oil from wood. In the Western countries, the refuse has also been tried as raw material. There the quality of refuse is entirely different from ours., and those contain high percentage of cellulose and is relatively dry. But Indian garbage is too much heterogeneous, wet and contains lot of dust, ash and ceramic and construction debris and as much pyrolysis is unsuitable.

Methanol Plant: A scheme for setting up Rs. 73 crore, 100 tonne/day methanol plant has been sanctioned in Maharashtra which will be located at the premises of Rashtriya Chemicals and Fertiliser at Chembur. Before committing to this expensive scheme of handling refuse it is worthwhile studying garbage in detail and test it in a laboratory or a tiny pilot plant to obtain data on various aspects of the process. Experience obtained from these tests plant can be compared with compost plants not only in Bombay and Delhi but with plants located at other areas of the country. Prima facie, pyrolysis of refuse or its conversion to methanol is extremely intensive in its requirements of capital and operating costs.

Bio-Gas Production: Anerobic decomposition of organic materials produces a gaseous mixture of methane and carbon-dioxide which is popularly known as biogas. The vegetable refuse from the cities is a good source of biogas. Experiments are being carried out at various places about biogas generation by using vegetable matters but as yet no commercially viable process or plant has been developed while the biogas plant in cities may not always be attractive, in rural areas its aqueous affluent that is rich in fertiliser can be used in the farms.

Burial: By this method a trench is dug and refuse and earth are dumped in alternate layers. After four to six months, the material gets composted and is usable. Upon filling of one pit, another can be dug. This process is sutiable for small communities.

Other Uses: Cattle Feed:- Kitchen and market wastes can be processed into nutritive cattlefeed, provided toxins and unacceptable inerts are excluded. Excel Industries Limited in Bombay is converting their canteen waste into feed for pigs.

Construction Debris: This rubish emanates from demolition, alternations, repair and construction of buildings and repair of roads and underground work of telephone, electric lines, water works and sewage system. Due to lack of co-ordination and heaped. These keep on spreading, affecting mostly pedestrians who are a lready facing hardship due to ill maintained and crowded footpaths. As per rules the producer of such materials is required to remove and dispose the same in designated places assigned by respective municipal wards. The practice is unworkable portion of rubbish remains unattended for long. A considerable portion for rubbish finds its way into storm water drains thereby choking the sewer system. Again the pedestrians bear the maximum brunt of this situation.

For new construction or even for repair and alteration to buildings, no raw materials, namely sand, aggregates, bricks and iron materials should be allowed to be stored in public places. The materials except very heavy and long ones get strewn all over the areas causing traffic and dust problem. A substantial portion finally passed to the storm water drainage system.

<u>Industrial Wastes:</u> Bombay has the largest concentration of industries in India. While some pollution is inherent, its abatement is also possible by industries themselves, whether big or tiny. Though there are enough government and municipal rules for good upkeep of the industries, a visit to any industrial area will reveal the way these rules are ignored. All concerned are to be blamed for this malice. Every industrial area is filthy, strewn with all sorts of wastes.

Some of the dumped materials are of a toxic nature. As Those contain some salable materials such as small metal parts and scantlings, rag-pickers are always found scattering the dumps to have their picks. When dumps become too large, those are set on fire making the entire area smoky and dirty with fly ash. The partly burnt materials finally find their way into the open gutters, which causes obstruction to flow of water resulting in temporary flooding even during non-monsoon days. Even for the large industries, the front is kept beautiful, and the rest and the rear present a dismal sight.

<u>Human Wastes:</u> Since independence, for betterment of one's prospects there has been tremendous population migration to the large cities, particularly to metropolitan cities. This process will continue for a long time. Most of the poor migrants live in the slums or on footpaths. Over 50 per cent of 85 lakh people of Bombay live either in slums or on footpaths or in the open where toilet facilities are either scanty or non-existent. Any open space is therefore used for excretion and urination causing health hazards, particularly to the children. Even the heart

of Bombay is engulfed with this problem. Human excreta provide the principal breeding ground for many hazardous pathogenic organisms, viruses, bacteria, protozoa, helminthes etc., all of which affect the human body. Micro-organisms are a potential source of infection, either through water pollution or through food.

An average person produces about 0.25 to 0.35 kg. of faeces and 1.00 to 1.3 litres of urine per day. Thus about 5 lakh tonnes of faeces and 20 lakh tonnes of urine are annually discharged in the open in Bombay. This is a potentially valuable waste for its conversion into biogas. A low-cost, public toilet that is low in its requirements of water, without being connected to sewage system and a matching bio-gas, plant have been designed which will be tried soon. This toilet will neither pollute the underground water with pathogens nor the ground with bacteria or hook work.

Generally all cities and particularly Bombay , offer livelihood to able-bodies and willing persons. It is estimated that 300 to 500 persons from far and near are migrating to Bombay daily. Most of these people are from very poor sections and they arrive as destitutes. Not finding gainful employment, they start picking up papers, plastics, metals and timber pieces from roads, garbage and industrial wastes. They continue this work as no prospective employer hires a person without any reference.

Although they are called rag-pickers, they do not pick rags. They pick reasonably-sized papers, plastic, glass etc., and leave alone the rags that are made of cloth. From early hours of the day till late night, they are found moving with a gunny bag and a stick. While retrieving the materials from public bins. Cubicles and open dumps, they scatter the garbage. Some civic minded people throw their garbage in plastic and paper bags. These men and women recover these bags by emptying them and litter the areas with their contents leaving the area filthy. After collecting such materials they meet at some convenient place on the roadside for grading their collection. The entire process is very unhygienic. These people are themselves carrier of diseases. Threafter they carry these assorted materials by train. On the Eastern side of the Grant Road Station in Bombay where there exists a big market for these filthy materials. One can notice men and women with head-loads of such materials moving in quick succession. There are such shops in other areas too. If municipality does not permit operation of these unauthorised shops, rag-picking will considerably come down and eventually it will reduce the number of migrants.

These rag-pickets earn between 20 to Rs. 30 a day for 10 to 15 hours work. The papers are sold between 50 paise and a rupee per kg., glass 50 paise per kg., and plastics Rs. 3 to Rs. 4 per kg. Getting the idea from rag-pickers municipal loaders and private sweepers of residential and office areas also collect of the assort papers and store them below and in the corner of the staricase and at the back of the buildings,

turing these areas as den of cockroach, lizards etc. The residents of dwellings and office owners should inspect their buildings and stop this bad practice of their sweepers.

People's Apathy Must Go: Years of inadequate facilities, unworkable laws, inefficiency and lack of enforcement of the authority, citizens negligence about social responsibility and of their own health have led to this situation. The process has to be reversed.

Solution: Given adequate and effective facilities, people will co-operate and be receptive to the introduction of effective technical innovation based on critical observations and sociological requirments. Installation of facilities coupled with enormous patience when dealing with the public will produce the desired results. Singapre is the world cleanest city an dBombay's Colaba Bus Depot is an oasis in the desert of filth. They became so by providing adequate facilities and insisting upon their use. The city of Singapre first provided adequate number of latrines and garbage bins and then authorised police to take strn action against violators. Firmness does not work unless there is fairness. Firmness without fairness leads to apathy and corruption. In Bombay the function of nuisance detectors of the municipal corporation and Bombay Police who have authority under law is totally ineffective as facilities either do not exist or are grossy inadequate. As a result violation of rules is on the increase. Adequate facilities are of immediate necessity.

Public education & co-operation: Any public work which has a sociological impact can be effective only with technological innovations based on public needs. Rules, regulations and legal actions can have little effect without adequate and proper facilities. Taking people into confidence and patiently educating the people for improving their awareness of the problems will achieve the desired results. The press, television, radio, educational institutions especially schools, forward looking citizens and philanthrophic organisations can play a significant role.

For carrying out this important and gigantic work, help form one and all is needed in the form of cash and kind. Efficiency for all aspects of work related to the management of wastes has to be increased. Any scheme evolved and found effective in Bombay will be effective not only in India but also in other developing countries. Let us face this; Bombay has always been a leader in civic matters, thanks to its reasonably alert municipal officials an dstaff in particular and enlightened citizens in general.

What has been achieved: The need of the city is management of its solid wastes from health and aesthetic considerations. Effectively designed community garbage bins and low-water, low-cost public that do not strain the sewage system are most needed. The design of such community garbage bins was taken up as its first project by 'UTILITY', a voluntary association of three engineers, a doctor and a lawyer. Taking various

factors into consideration, a community garbage bin designed from the basics was put into use in January 1982 with the approval of Bombay Municipal Corporation. It helped transform previous garbage dump areas into a clean area to be used as a badminton court. With the removal of the bin, the are again become dirty.

With the experience gathered from further experimentation with different types of garbage, ten experimental multi-advantageous community bins were installed in various places of Bombay. The users as well as municipal loaders found these easy to use.

Small kitchen bins and large steel bins for use by markets and hospitals from which refuse could be directly dumped into the truck have been designed. After studying the pros and cons of low-water, low-cost public toilets being experimented in India and in various South-East Asian and some African countries,, a design that will be most suitable to Indian conditions is under preparation taking care for preventing pathogen and bacterial contamination.

PLANNING AND ORGANIZATION OF SOLID WASTES MANAGEMENT SERVICES *

- Dr. S.R. Shukla **

The solid wastes management of a city would normally include:

- refuse collection
- street cleansind and probably gully emptying,
- refuse disposal
- administrration: budgetary control, Wages stores, statistics.

In developing countries it has been found that the operation of all these services absorbs from 2 to 5 manual workers/ 1,000 population and one heavy motor vehicle for about 20.000 population. In certain countries the high ratio of manual workers to population arises through the employment of a large proportion of the workforce on street cleansing: this is sometimes because of enfficient sweeping methods but often because of inadequate refuse collection services, a consequence of which is that a significant proportion of domestic and shop wastes are collected in the form of street refuse.

It is probable that in most cities, given good methods and sound management, efficient services could be provided with a ratio of 2½ to 3 manual workers/ 1,000 population. Even on this scale, however, the labour force to be controlled is very large, about 1.000 men for a city of 400,000 population. The effective deployment of so many workers demands that day-to-day control should be decentralised into partially autonomous groups, each headed by a leader of

---

* Reference: Management of Solid Wastes in Development Countries by Frank Flintoff, W.H.O.

** Assistant Adviser(PHE), Ministry of Works and Housing, New Delhi.

suitable quality and training.

Thus the basic organisation for refuse collection and street cleansing shouls be a group of about 50 workers controlled by an Inspector. The size of this group can be greater- 100 or more in densely populated are, but for these larger groups the inspector requires an assistant. The are controll d by a inspector can be called a district in a city of medium size. A sub -district in a big city.

It is sound management principle that middle and senior management should control no more thanfive junior management units. In l rge cities, therefore, five sub-districts would form one districts headed by a District Supervisor, five districts would forma division headed by a Divisional superintendent. At the head of this hierarchy will be the officer responsible for the operation of refuse collection and street cleansing within the solid wastes management department.

Such an organisation cannot operate efficiently without a physical infrastructure of the following kinds:

- sub-district depots in connection with transfer (stations)
- district offices
- divisional officer(in large cities);
- central offices for senior management of
- the various branches of solid waste services.

<u>Qualifications for Management:</u>

In a large city the director of the departments and the assistant director should be engineers of a discipline appropriate to their main responsibilities, for example:

Operation - Public health engineer
Mechanical services- Mechanical/electrical engineer
Sanitary landfill- Civil engineer
Administration- Commerce graduate or economist

For the operational control of refuse collection and street cleansiing solid wastes management technicians are necessary, having a basic educationa. to high school standard and a diploma in in solid waștes management.

Labour Relations:

A major problem of man-management is that of maintaining the inbarest of the average worker in his dull and repetitive job. Highproductivity can be achiaved only when motivation is good and some measure of creative satisfaction is provided.

The best appraach is that of regular consultation with the worker in ordersto elicit complaints and suggestions, and also to inform them on management problems and policies, particularly proposals for change in methods.

The exgent to which these consultations are formalised will depend to a large extent on industrial organisation. Where most of the men are members of a trades union, consultation will be structured and some of the initiative will come from the workers's representatives.

Even in the absence of unions, consultation and interchange of views should be strongly, encouraged at all levels. They are particularly productive at district or sub-district level, because here ever man is known personally by the inspector. Senior managers should also consultdirectly with workers, informally during day-to-day contacts and more formally, perhaps through divisional meetings, when major policy issues need to be discussed.

Health and safety

Management at a levels should be vigilant in providing the maximum protection of worker against risks of accidents and ill-health. The following are important issues:

- the regular use of protective clothing
- avoiding dangerous methods of riding on vehicles
- hydraulically tipped vehicle bodies sometimes descend suddenly without warning men should not stand underneath them
- All cuts and animal bites should be reported without
- delay in order that first-aid or medical treatment can be provided
- personal hygiene should be encouraged by the provision of shwers for use before leaving work.

Planning a Refuse Collection Service

The Planning and introduction of a re-organised refuse collection service is a complex procedure that may extend over several years and contains four stages;

- a preliminary study to provide guidelines for the tosting of what appoar to be suitable met ods,
- one or more pilot projects to test proposed systems and esta blish work performa ce and costs
- production of a Master Plan based on system that are a phased progra mme of implementation of the Master Plan.

Preliminary Study

The study should have clearly defined objectives which may include:

Health and aesthetic aspects: For example wastes must not be exposed to vectors, animals or acavengers during storage collectors must not suatain skill contact with wastes during collection.

Systems: A system must satisfy the specific needs of that area of the city where it is be applied; thus multiple systems will probably be necessary.

Mechanisation: Labour-intensive methods should be used unless machanisation producers a positive reduction in total

expenditure, or is necessary for health protection. Indigenous equipment: Indigenous vehicles and plant are to be used for at least 90% of all investments.
Productivity: High productivity will be sought by method and time studies and priority gi en to ensuring high vehicle productivity.

Traffic: Methods should avoid interfering with traffic as fas as possible; this implies that animal carts should not be used in the city centre and that motor vehicles should not be parked on the highway for protracted loading periods.

The first step in the preliminary study will be to obtain estimates of wastes generation from the main sources; domestic premises; shops and markets offices and institutions. Street refuse should also be estimated because it may be handled through refuse collection transfer points. It is also necessary to know the density of the wastes at source, and use ful to know the physical constituents.

A broad physical survey of the city is then undertaken to divide it into areas of similar characteristics on which tentative storage and collection proposals could be based in the light of existing knowledge and available equipment.
For each type of area t e following issues are considered:

Storage

Communal storage system of small capacity and short spacing, enclosed, with detachable liners capable of being handled by not more than two man.

Storage in the home, bin capacities for dwellings of various thpes, and for various collection frequency. Bin capacities required at shops. Storage at markets, schools, hotels and other large wastes producers.

potential use of chutes, and the types of containers to be used in chute chambers. Responsibility for the provision of containers, owner, occupier or municipality?

Collection:

Frequency of collection for various areas. primary collection vehicles, design of handcrafts; animal carts, vehicle capacities in relation to density of wastes from various sources. Short-range transfer system, trailers, skips, spacing of transfer stations inareas of various population density, design of transfer stations, list of potential sites. Potential use of collection in shopping areas and single dwelling areas: selection of potentially suitable vehicle types.

potential for mechanised small containers of 1-2 cubic metres at schools hotels and large stores. Relationships between collection systems and location of disposal site: vehicle capacity inrelation to length of haul; relay systems.

At the conclusion of the preliminary study it should be possible to define the main type of area for which different solutions will be necessary, probably randing from city centre prestige (shopping to shack communities) and for each situation and or more tentative proposals together with possible scales of cost.

Pilot Projects:

The next stage is to test on a limited scale the most promising of the possible solutions that have emerged from the preliminary study. The purpose of the pilot tests

would be to obtain the following information:

- accurate work performance for manual labour and vehicls, as a basis for route planning at the implementation stage,
- accurage costs, for comparing rival systems, and for accurate estimating of investment programme and annual budget,
- to try to judge the impact on health and environmental standards of the systems under test.
- to measure public accpetability of the new systems, without which it would be useless to adopt them.
- to judge the acceptability of the new methods to the workers, because their support is also a vital ingredient,
- to find whet modifications are neded to equipment and vechicles.

A pilot project normally requires at least 1½ years. because it should run for a complete year in order to cover seasenal changes which occur in vastes generation, and it must be precedend by a period of detailed planning. There may also be delays in accuiring the equipment needed to operate it.

The siae of pilot project is usually determined by the minimum size of an operating unit. For example, the minimum for primary collection by handcart would be one transfer units, say a trailer, thus about six collectors should be employed, and they would serve about 1.200 dwellings. For communal countatners, however, a more dozen would be sufficient to judge their efficacy, and to obtain standard times for emptying them. Thus the population range for pilot project may be betwsen 2,000 and 10,000.

It is of the utmost importance that a pilot project should be continuously supervised and detailed resul s recorded throughout the whole of the testperiod. Each project may require staffing on the following scale in addition to the workers operating it:

1. Project manager,
2. Supervisors
3. recorders 6 for double shift operation,
4. Social workers.

The social woekers have the important task of maintaining a continuous dialogue with residents, to guide them in making best use of the service being previded, to gain a high level of cooperation and to measure the acceptability of the method being employed.

Master Plan

The results of the pilot projects, judged in the light of cost, public acceptability, and the extent to which primary objectives can be met, can form the basis for a Master Plan which would be implemnted by a phased programme over several years.

The Master plan would define the system to be adopteed in every given situation, and would estimate the proportion of wastes from all sources to be handled through each system. On the basis of these estimates, equipment requirements for the whole city can be defined and estimates prepared for capital and operating costs.

The plan would also stablish the geography of operation and control; the locations of transfer points, depots, and offices, and would include standard designs for depots and transfer stations.

Implementation

Implementation of the Master plan may involve a complote re-organisation of the refuse collection services. Itwould impose a very heavy managerial load and it would probably be necessary to place the reorganisation process in the hands of a special project team whose leader ranked as a Deputy Director, in order to allow normal standards of control of current operation to continue.

Training in the new methods would be necessary for manual workers arnn techniques, an convenient way of achiaving this is to maintain the pilot projects in operation as training grounds during the early period of implementation.

It is probble that a large building programme may be necessary to provide the physical infrastructure for the now methods and it is certain that a l rge amount of equipment would have to be acquired. The capital expenditure involved is a further reason for phasing implementation over several years.

It is likely that implementation would also involve some changes in the management str-cture, at the very least some of the beundaries between sub-districts and districts may have to be rationalised. The sub-listrict or district, havin a population in the range of 20,000 to 50,000 in the recommended basis for re-organisation. In the first year it may be prudent to undertake only one or two districts. In a city with 40 districts phasiing could be on the following scale:

I st year	3 districts
2nd year	5 "
3rd year	19 "
4th year	10 "
5th year	14 "

The speeding up of implementation in the later years is possible because derailed route planning can be undertaken continously by the project Team and also because after the first two years a large number of trainied personnel will be available for temproprary transfer to districts under reorganisation.

It should be atresed that implementation requires the some care in planning and supervision as the pilot project, but for a shorter period. Every collection rout must be precisely defined in writing with every single scures listed, and during the first few days of operation a superviser must continously accompany the collector of the crew, to advise and train them, and to monitor their working rate.

The success of the implementation programme will depend to a large extend on public relations. Every medium should be used to inform the public of the objectives and to advise them on the duties they must perform as part of the service. The best method is always personal contact. Elected representatives should pay visits from house to house in a district under reorganisation. Social workers should be involved in areas where there are particular difficulties of communication with the people. The press and radio are obvious methods of instruction and publicity. School teachers should be fully informed about the Master plan so that it can be discussed in classes.

.-.-.-.-.-.-.-.-.-.-.

SOLID WASTE MANAGMENT: PRESENT STATUS AND FUTURE PROSPECTS

P.S.A. SUNDARAM

THE PRESENT paper describes the structure and role of the authorities and agencies concerned with solid waste management in India. Certain new developments in the institutional field are then traced and future prospects in this area are highlighted.

ORGANISATION AT THE CITY LEVEL

The municipal bodies in India are entrusted under law with the obligatory function of conservancy of public cleansing and scavenging work. The term 'solid waste management', in the sense of a total system covering all processes from the collection to the disposal stage for all types of refuse, not to speak of resource recovery, is not in vogue in most municipalities, nor does it find a place in legislation or executive orders relating to sanitation. In the Indian context where sewerage facilities are available only to about 19 per cent of the urban population, that too mainly in class I cities, a considerable portion of the latrines are not connected to the sewer system, nor are they of the water-seal type. Besides, a significant percentage of the population use public latrines. Conservancy, in these circumstances, includes both the solid waste and nightsoil.

The conservancy activity is usually entrusted to the health department of the municipality in almost all cities. This is because of the association of sanitation and public hygiene with public Health- the latter subsuming other activities like prevention of diseases, licensing, slaughtering of animals, running of hospitals, etc. The health officer is assisted by a number of sanitary inspectors, etc. The city is divided into a number of administrative divisions, each comprising a few electoral

wards. One sanitary inspector is placed in charge of a division and supervises all operations relating to collection and storage of waste. The transport of waste is done by mechanised and non-mechanised modes to disposal sites within or outside the municipal limits. The night soil and garbage are usually dumped in the same disposal site. The transport vehicles are maintained by the engineering wing. In some major corporations like Delhi, the conservancy wing is separted from public health and placed under an engineer, called the Director of Conservancy.

For street sweeping, collection forefuse and for loading and unloading the refuse from the vehicles, the municipalities employ a large number of conservancy staff. Some of them also undertake the collection of night soil and cleaning of latrines, both public and private. The normal practice is that the householder dumps the house refuse in a dusthin located nearby on the side of the street. The municipal sweepers also sweep the roads and fotpaths, collect it in their bins, and dumpt it in the dudustbins. The garbage stored in the bins is loaded by the conservancy start on the bullack carts (in smaller towns), or trucks, which call a least once a day near each collection point. In certain cases, garbage is transferred from the bins located in the narrower streets by the civic staff in large barrows both main streets for further transport. In market areas, slaughter houses and public places, the municipal sweepers collect the garbage and store it in a large central bin to be transported away. The night soil in unsewered areas is transported in wheel berrows to collection points from where it is carried away to the dumping site.

A survey of 200 municipal bodies of cities of all sizes revealed that the percentage of conservency to total staff varies from 44 per cent in the lowest size to 66 per cent in the class I cities. In terms of the number of conservancy staff employed per 1000 population, however, the local bodies are inadequately

staffed, the figure ranging from 4.6 to 5.5 The cities in the population range of 50,000 to 100,000 were found to employ the maximum staff. Conservancy accounted for 26 to 30 per cent of total municipal expenditure on all services. Some bigger municipal bodies spent as much as 60 per cent on conservancy. It was found that the system was biased towards collection of garbage up to the bins in smaller towns, instead of laying more stress on collection from the bins and adequate disposal.

COLLECTION OF COMMUNITY WASTES

Community wastes collected in Indian towns are made up of heterogenous meterials. These contain articles and things of various sizes and types from the dust of the roads to large metal containers; from vegetable leaves to fragments of wood; from pieces of paper to large paper-board cartons; from glass bottles to worn out tyres; from fragments of bones to carcasses of animals; clothing, cotton, residue of fruits and vegetables, etc. The character of refuse often depends on the type of activities carried on in the towns. Roughly 50 per cent of the refuse is found to be fermentable. The density of the refuse is around 500 kg./ cubic metre. It is estimated that the output of urban refuse amounts to about 0.3 kg. of household refuse, city wastes and commercial wastes, 0.2 kg. of nightsoil and o.8 kg. of urine per head per day. The quantity of dry refuse is higher in bigger cities and comperes with countrises in Europe. In addition to these components, other items like cattle wastes, slaughterhouse wastes, sullage water, sewage sludge, etc., are important in bigger cities. In overall terms, the refuse collected from urban areas would be about 33, 000 tonnes per day or 12 million tonnes annually, besides 22,000 tonnes of hightsoil per day. The manurial value of the refuse and nightsoil would be about 212.450 tonnes of nitrogen, 137,965 tonnes of phosphoric acid. 181,785 tonnes of p otash and 658,800 tonnes of calcium.

The refuse collected from various points is disposed of by different methods in different towns, viz., dumping, sanitery landful and composting. Majority of smaller municipal bodies adopt dumping due to non-availability of mechanised forms of transport. Generally, the low-lying areas and the outskirts of the towns are used for this purpose. However, they constitute a health hazard and become a breeding ground for flies and mosquitoes. Sanitary land fill is properly practised only in larger cities like Delhi.

For preparing compost from the refuse, both manual and mechanical methods are use. However, the manual process is more prevalent because of the lesser cost and skilled staff needed. There are two types of manual composing used; the Indore process and the Bangalore process. In the Indore process, nightsoil mixed with street sweepings and domestic refuse are placed in a shallow, open masonry pit in alternative layers, each three inches thick, upto a depth of five feet. The material is turned in the pit for every two weeks for a period of eight weeks, and then stored on the ground beside the pit for a month without turning. The composting action is both aerobic and anaerobic. In the other process, a number of earth trenches is constructed. The fresh material is placed in alternative layers and eventually covered with earth. Instead of turning over, the material is digested under anaerobic conditions over a period of five to six months. The averagenitorgen value of the compost is 2 per cent. Many cities produce compost by either of these processes which is sold to the agriculturists nearby. They earn an income ranging from ₿ 15.000 to ₿ 20,000, often exceeding the cost of preparation of the compost. With better management of the operation on scientific lines, and with greater financial assistance from the government, both the revenue and output would be higher.

Mechanisation in composting has been introduced in a number of big cities with the objective of speeding up the process of aeration and bacterial breakdown of materials and production of equality compost. It has been appreciated that an unmodified adoption labour surplus and the substantial vegetable content of the urban waste, is not suitable. The Widrow composting has been preferred among the different processes despite its requirement of more land and labour. An expert committee drew up the guidelines for constructing machanical compost plants suited to Indian conditions. It was appreciated that it was not possible to operate such plants with a profit motive through they could be largely self-supporting. It was necessary to ensure the quantity of compost and its easy marketability. As suggested by the committee, assistance was provided by the central government during the Fifth Five Year Plan period in the form of capital subsidy and grants for infrastructure items to enable the construction of mechanical compost plants and the conveyance of adequate soild waste. So far, eight plants at Ahmedabad, Baroda, Bombay, Bangalore, Calcutta, Delhi, Jaipur and Kanpur cities have been commissioned. Some of the problems faced by the operating plants include high cost of production, lack of demand, inability to steel compost at the economic price. The whole experience is being evaluated by the National Environmental Engineering Research Institute in order to suggesc suitable technology, scope for standardisation and reduction in costs, enrichment of the compost by other nutrients, improvement in marketability of the compost, better management of the compost plant, etc.

PROBLEMS AND PROSPECTS

It would be clear from the above narration that soild waste management in the accepted sense of the west is practised in very few cities in India. Conservancy has some how been treated as a local function, to be discharged largely through local

inietiative and expenditure, and not calling for a major investment effort by the state government. The breakthrough came with the introduction of a scheme for central assistance in 1974 for assistance to cities with a population exceeding 300,000 to constcuct mechnical compost plants and to improve the infrastructure for soild waste management. This central government initiative resulted in the contruction of some plants and generation of considerable enthusiasm for the management of the whole sector. The cassation of central assistance for compost plants has put a damper on major capital investment, since neither the state governments nor the financial institutions have stepped in to fill the branch.

Despite the financial constraints faced by the municipal bodies for major capital investments for solid waste disposal, it has been increasingly realised by the bigger local bodies that much could be done with little investment to improve the systems of collection, storage, transport, refuse and disposal of urban waste. They appa ciate that failure to deal with the ever increasing flow of liquid and solid wastes, arising from population growth and rapid urbanisation, constitutes on alarming threat to Public health and environment. The approach has been to develop an integrated system with the objectives of (a) improved cleanliness and reduced pollution of the environment; (b) eliminating the practice of manual handling of nightsoil and other urban refuse by the provision of suitable handling equipment and by installing low cost systems of sanitation, and (c) producing enriched compost for agricultural production, or a commercial form of energy. The local bodies also feel the necessity to treat urban wastes as a major material handling project where industrial engineering methods have to be employed. Through discussions in periodic meetings, and through advocacy, the central and state governments seek to buttress these new approaches.

Since the local bodies are creatures of State Laws basic changes in the existing law may be required enjoin on the local authorities to ensure scientific and hygienic treatment and disposal of urban wastes. The law at present emphasises only the storage on generating points, collection therefrom, and transportation to the disposal venues; it is silent on the final disposal. The law is not sufficiently rigorous in respect of penalitise for throwing rubbish indiscriminately by the householders or the vagrants. There is considerable variation in the provision of different state laws relating to urban waste. They are of an enabling nature, and do not exect a minimum performance from the local bodies in respect of service rendered, frequency of collaction, and the method at disposal. The law does not cover the whole gamut of domestic, commercial, agricultural and industrial waste. There would thus appear to be need for a separate comprehensive law dealing with solid waste management, or at least a condification or the required provisions in the municipal law. Such a law could cover the entire waste management system at the local level, responsibilities and role of the local bodies as well as the state government, people's participation, rights and obligations of trade and industry, finance, institutional arrangements for training, research, data collection and dissemination. While the local bodies would be the sole executive authority in the rield for the purpose, the state governments could assume responsibility for state level planning, overseeing the implementation of schemes, administrative, technical and financial support, etc. The role of the central government could cover policy lead and guidance, development of central information system, promotion of indigenous technology, setting up of standards, research and training. They would also identify proposals for assistance by central government and foreign donor agencies.

Arising from the realisation of the need to integrate solid waste management with urban development, the world Bank assisted projects in Calcutta, Madras and Kanpur contain a componant of solid waste management. This provides for an indepth study of

Contd/...

the existing systems of waste management including solid waste, nightsoil and other liquid flows, as also the capacity of the existing civic body to manage the system with tolerable efficiency. On the basis of deficiencies identified by the study, investments are made for the procurrement of equipment such as hand carts and wheel barrows to assist the conservancy staff, as also tippers, loaders, trucks, and compacters for collecting and transporting the refuse. Transit collection stations are constructed in a hygienic fashion and the dustbins are erected imaginatively to avoid spillover of garbage and fly nuisance. Nightsoil collection is seperated from the storage, collection, and transport of refuse. The problem is tackled in the short term by providing for 100 percent removal of nightsoil from the all households by conservancy staff provided with improved aids and by provanting the dumping of nightsoil anywhere except in designated spots. In the long run, efforts are being made in big way to convert all dry latrines to water seal latrines connected to double chambers through a system of monatary incentives and municipal initiative. The UNDP is supporting the preparation of feasibility studies for selected towns.

MANAGEMENT OBJECTIVES

In Bombay and Delhi, as in other cities, it is recognised that solid waste management is much more than keeping the roads clean, and the activity is managed by an engineering wing in close coordination with the health staff. It is responsible for public cleansing, maintenance of vehicles and equipment, management of landfill sites and for composting. Of course, the fact that these two municipal corporations are comparatively more affluent anables them to devote more staff and resources to this activity. Nevertheless, the objectives similar to those sat for itself by the Bombay Municipal Corporation represent the direction of future management of the sector are set out below:

Contd/...

(i) Achieve complete removal of the refuse generated, by establishing reasonable frequency of complete removal for various types of collection points and regions.

(ii) Maxmise the use of manpower and equipment for the transportation of refuse by planning collection systems using fixed routes and standard programmes.

(iii) Rationalise the use of manpower for public road sweeping and for collection of refuse from public places.

(iv) Introduce a total change in collection equipment by employing low-loading height, closed body, mechanical-loading, compacting type vehicles.

(v) Increase the use of supplemental transportation of solid wastes(transfer stations) for economic transportation of refuse to final disposal sites.

(vi) Introduce sanitary land-filling method for disposal, and explore measures to put the refuse to fruitful use by making compost or forms of energy.

(vii) Establish separate facilities for refuse transport and other equipment maintenance for the solid waste management-department for better and more systematic equipment management by providing new workshops and garages.

(viii) Provide an effective organisation by change in the present structure of management and a continuous personnel development programme.

Contd/...

(ix) Introduce a better system of planning and control by proper communication system such as control stations equipped with wireless and periodic reporting . Establish and operate public communication system.

(x) Establish a laboratory for the analysis of refuse to generate data on the trend of refuse quality for effective long range planning.

(xi) Provide housing and other facilities for the labour and supervisory personnel. Introduce a system of incentives.

(xii) Integrate solid waste management with health, slum improvement, road maintenance and other sectors.

Given these objectives of solid waste management, the problems and constraints faced by the local bodies also need to be appreciated. One is the almost universal inadequacy of funds to undertake a major overhaul of the system and meet the requirement of additional vehicles and equipment. Another is the generally low priority accorded to this sector despite the significant perfentage of the revenue budget devoted to the conservancy services. The third is the lack of resourse to funds from the higher levels of government and financial institutions as far as the smaller municipalities are concerned.

THE PROBLEM AREAS

Some of the other problems are:

(a) Shortage of experienced and qualified staff to operate the total system at different levels;

(b) The tremendous increase in the growth of population and expansion in urban areas;

Contd/...

(c) The emergence of slums,footpath dwellers and unauthorised settlements creates totally unhygienic conditions. Even when basic services are provided, it is not possible to maintain them due to lack of community support, unwillingness to pay service charges, and inadequate conservancy staff to meet the special problems of removing the refuse;

(d) Due to overall increase in the educational standards and the perceived unattractivancess of the conservancy service, the manpower suitable for this work becomes scarce, and this strangthens the hold of the labour;

(e) Unplanned developments and location of activities make collection of refuse difficult;

(f) Public apathy and entrenched habits and attitudes relating to sanitation hamper an effective aperation of the system;

(g) Difficulty in acuuisition of suitable lands for composting and for location of collection points; and

(h) Lack of transport facilities to carry the refuse to disposal sites and problems of maintenance of vehicles and equipment.

A great deal of research has been done in the country on the recovery of energy from solid waste. In consonance with the emphasis placed by the international community on renewable sources of energy, the Government of India has set up a Commission for Additional Sources of Energy to support projects for generating additional sources of energy such as biogas and electricity from wastes.

The processes under investigation in Bombay and Delhi include:

(a) using heat liberated during incineration to raise steam which can be used to generate electrical power;

(b) decompose organic matter through the application of heat in an oxygen-fees environment or with deficient air. This process of pyrolysis can yield fuel such as char and ash in varying quantities; and

(c) biochamical processas involving anerobic digastion of solid waste to produce methane gas of pipeline quality.

Thus, the central government is becoming intansively involved in the quality of solid waste generated in the citiss and their fruitful utilisation as compost or energy. It has also offered to provide financial assistance for innovative schemes to recover anorgy from waste.

CONCLUSION

The above analysis would give an idea of the present status of solid waste management in different urban areas in India. In a country as vast as India, the conditions vary considerably. However, the general picture of pradominant local responsibility for solid waste management, with whatever resources, attention and staff they could command, remains. Concrete assistance from the central and state governments in the form of funds, technical guidance and training for the personnel has been forthcoming in recent years. There has also been a conscious attempt to intagrate this activity with general urban development and economic processes like manufacture of compost and generation of energy.

****

SAMPLING METHODS

Frank Flintoff

Generation:-

The generation of solid wastes varies in different types of dwelling as well as in different socio-economic groups.

Generation in relation to collection and disposal:-

The following are the methods commonly used to estimate the total quantity of wastes to be callected and disposed of:

-- average loads collected/day multiplied by average volume/load ascertained by measuring a vehicle body, and converted to weight by using an average density obtained by sampling;

-- sample vehicle weighings, using a weighbridge, the average being multiplied by the total loads/day.

-- weighing of every load on a weighbridge at the disposal site; this is the only accurate method.

Measurement of the total weight of wastes delivered to a disposal site, however, is seldom an accurate indication of wastes generated, as distinct from collected, because of losses at various stages. The following may be a typical pattern:

State Handling phase	Losses
Total Generated	
1	Minus salvage sold by householder
2	salvage by servants
3	salvage by scavengers
4	wastes disposed of by unaughorised means, e.g. on unused ground or in ditches.
Total Collected	
5	Minus salvage by collectors
Delivered for disposal	
6	Minus salvage by disposal staff
	salvage by scavengers
Total Disposed of	

For ceryain purposes, e.g. to determine the volume required for storage of domestic wastes, or to find the recycling potential of wastes, it is necessary to try to measure wastes actually generated. This can be done by sampling at source, i.e. at stages 1 or 2.

<u>Requirements for estimating domestic and trade wastes:-</u>

Because the cycle of domestic activity varies throughout the week, it is necessary to obtain samples that precisely cover one week. For India the following initial assumptions could be made:

350 gms/person/day

6 persons-family,

= 2.1 kg/dwelling/day = 15 kg/dwelling/week

(including natural moisture content)

However, there is a very wide range of wastes generation as between socio-economic groups and dwelling types, thus it is necessary to obtain samples from every identifiable group. The following is a typical classification :

Code	Dwelling type	Socio-economic group
A.1	Single unit	low
A.2	"	Medium
A.3	"	high
B.1	Multiple, low rise	low
B.2	"	Medium
B.3	"	high
C.1	Multiple, high rise	low
C.2	"	medium
C.3	"	high
D	Shop and office wastes	

The classification must reflect the character of the city and in some cases it would be necessary to include slums, bustees and semi-rural areas.

The minimum size of a sample for a group of similar dwellings is about 200 kgs; thus the minimum number of dwellings required per group for a daily collection would be about 100, based on the assumed rate of generation above.

The minimum number of 200 kg samples required for a city is about 12. Thus, if the number of classified groups is less than 12, more than one sample should be obtained from the largest group or groups.

On the above assumptions, a generation test in an Indian city would involve about 12 samples/day, each from about 100 dwellings, and would cover 1,200 dwellings and a population of 7,200.

Proposed method of collection of samples:-

In cities where the storage of domestic wastes is in communal containers, it will be necessary to supply every dwelling with a container for the period of the tests; plastic bags offer the cheapest solution.

After selection of the sampling areas, each householder should be interviewed, to explain the purpose of the sampling project. It is desirable that this be done by social workers who are better trained in communication. An explanatory leaflet should be left at each dwelling.

The sampling programme should extend over eight successive days. Wastes collected on the first day should be discarded as the period they represent may be doubtful; wastes collected from the 2nd to the 8th day will represent one week's production.

The collector should carry a supply of plastic bags, one of which should be handed in at each dwelling in replacement of the full one collected. Each full bag should be labelled with its appropriate classification before being taken to the depot where the contents are weighed and the volume measured.

For calculation of total weight and volume generated in the city, a multiplier is used for each coded group based on the proportion of the population represented by that group. For example, if the A.1 sample is from 600 persons and the total population in that classification is 40,000 then the multiplier would be 66.7.

In most cases, samples collected in this way would also be used for physical analysis, as described in the succeeding section, supplemented by samples representative of trade and commercial wastes.

The labour requirement for a programme of this kind is as follows:

Total calls/day for 1,200 dwellings	1,200
Calls/collector @ 20 calls/man/hour for 6 hours day	120
Number of collectors required per day	10
Period for which required days	8

(A basic weakness of this method of estimating generation is that, despite explanations given in advance, the

householder may vary the normal pattern of wastes disposal for personal reasons if he or she knows that the wastes are going to be examined. Greater accuracy is assured when samples can be obtained without the knowledge of the householder; this applies in Britain where the sampling collectors simply move in a little earlier than the normal house-to-house collectors. This is not practicable, however, in cities where the main storage methods are communal.)

Collection of samples from communal containers:-

For many purposes, such as deciding the design of refuse collection vehicles and the method of refuse disposal, collection of samples direct from source is unnecessary, and samples can be taken from communal containers or transfer stations. This is a much simpler procedure and requires merely the daily collection of at least 12 samples, each at least 200 kg or 500 litres, from areas which properly represent the selected socio-economic groups and trade sources.

The density of samples collected in this way will be higher than for samples collected direct from source because the density of the wastes increases at each stage of handling, partly through the removal of light constituents such as paper, and also by compaction of material at low level by pressure from the weight of wastes above, and lastly by the gradual filling of interstices by dust.

(Thus for the calculation of domestic and trade wastes storage capacity at sources, the density of communal wastes should be reduced by at least one third).

Analysis and Projection:-

The physical analysis of wastes, using an accurate sampling method, enables the following information to be obtained.

- density of wastes,
- proportions of salvageable constituents,
- proportions that could be incorporated in compost,
- combustible proportion,
- graded particle size.

Three or four analyses are needed over a period of one year in order to cover the seasonal variations that occur as a result of the climatic cycle and the food production cycle.

Collection of samples:-

At least 12 samples and not more than 20 are required, each of at least 500 litres and not more than 1,000 litres. The samples should be selected to represent commercial and market wastes as well as the domestic wastes sources referred to in the proceding section. The number of samples from each group should be proportianate to the population represented by that group, or also mathematical weighting could be used. If the purpose is to obtain information on collected wastes, samples can be taken from vehicles as they

arrive at disposal sites, so long as the source is known with accuracy, or from communal storage points.

Method of analysis:-

Samples should be analysed within two hours of collection to minimise errors from moisture loss. The measuring box of 500 litres is filled by shovel; the contants should not be compressed but the box should be rocked back and forth three times during filling. The box is then weighed to find the density of the wastes. It is now necessary to sort the wastes by hand into the required constituents and they are transferred in suitable amounts from the box to a sorting table. The surface of this table is formed by a wire mesh grid of 50 mm, so that all material below this size will fall throught it. The oversize vegetable-putrescible wastes are left on the table but all the other constituents are picked out and put in a marked container for subsequent weighing. Small hoes are used to turn over the wastes during the sorting process. When sorting of the oversize material is finished the table is shaken to ensure that everything below 50 mm has fallen through. The matter remaining on the table is vegetable-putrescible over 50 mm.

The matter below 50 mm which has fallen to the ground is now shovelled up and passed over a hand screen of 10 mm mesh. The wastes remaining on this screen are now hand-sorted until only vegetable-putrescible matter remains; this is the 10 mm - 50 mm size.

By this time the wastes are completely sorted into the required constituents and sizes except that the fine matter below 10 mm will be a mixture of inert and organic matter, such as sand and food grains. The proportions can be established only in a laboratory by moisture and ignition tests, but with experience it is possible to make a fairly accurate estimate by visual examination.

Information from analysis:-

Constituent	Sample No. and % by weight
	1 2 3 4 etc. Max Min Average
Vegetable/Putrescible	
Above 50 mm	10
10 mm - 50 mm	35
below 10 mm	10
Total	55
Paper	15
Metals	5
Glass	4
Textiles	3
Plastics & rubber	2
Bonos	-
Misc. combustible	2
Misc. incombustible	4
Inert Matter below 10 mm	10
Total	100
Density Kg/cum	350
Source of Sample Code letter	

<u>Equipment required:-</u>

1 measuring box, 1 metre high x 1 metre long x 500 mm wide, with bottom. Weight should be minimised by using thin resin-bonded plywood for construction. A strong batten should be bolted along each side, projecting at the ends, to provide four lifting points for placing the box on a scale.

1 sorting table, about 1.5 metres wide x about 3 metres long, made from a stout softwood frame with corners halved and bolted, and entirely covered by wire mesh of 50 mm, carried round every side and recurely fastened. The table can be supported on trestles or fitted with legs. 1 hand-screen of 10 mm mesh,

10 bins or boxes of about 60 litres to contain sorted material,

3 large flat shovels,

6 hand-hoes to turn over wastes during sorting,

6 pairs plastic or rubber gloves for sorters,

1 platform weighing machine, preferably with capacity up to 500 kg.

<u>Projections:-</u>

Analyses are often made as part of feasibility studies for refuse treatment such as composing and incineration. Such plants have lives of twenty years or more, and in

Such cases it is vital that the design parameters should be based on projected and not current analyses if performance is to be reasonably uniform throughout the working life of the plant.

Over a long period it is likely that changes occur in the physical characteristics of wastes, from the following causes:

- a rising standard of living increases the production of solid wastes, particularly constituents other than vegetable-putrescible,
- changes in packaging technology and retail distribution methods tend to increase packaging materials and velume per capita,
- changes in domestic fuels, for example a reduction in the use of solid fuel, could cause falling ash content and a reduction in weight per capita.

In cities where annual analyses have been carried out for 15 years or more, changes of this kind apper on a graph as a smooth curve from which it is usually possible to extrapolate estimated analyses for up to ten years ahead. Where such information does not exist, it is possible to make projections based --------- upon national and local forecasts of economic growth and industrialisation.

Basic Collection Systems

Frank Flintoff

Four basic collection systems have been evolved in relation to the amount of work imposed upon the householder:

- communal storage which may require delivery of the wastes by the householder over a considerable distance;
- block collection, where the householder delivers the wastes to the vehicle at the time of collection;
- Kerbaside collection, where the householder puts out and later retrieves the bin;
- door-to-door collection where the collector enters the premises and the householcer is not involved in the collection process.

Collection from Communal Sites:-

The organisation of refuse collection is greatly simplified by the use of large communal storage sites. The city of capacities from 0.5 to 10 tonnes for a population which exceeds 4 millions. Delhi probably has about 300,000 separate sources of wastes (dwellings and shops) and a frequent collection direct from every source would require a much more complex organisation and possibly greater expenditure. However, when sites are widely spaced, a great

deal of domestic wastes are deposited in the streets by householdes too laxy to carry it to the depot or masonry enclosure. It is significant, therefore, that only by employing about 10,000 sweepers Delhi is kept in a tolerable standard of cleanliness.

While the use of large communal sites may appear to be a fairly cheaps and simple solution, it may transfer much of the burden of refuse collection on to the street clearing services and actually increase total costs, because it is cheaper to collect refuse direct from a house than to sweep it up from the streets. In Delhi in the year 1974 Rs. 31,000,000 were spent on sweeping, only Rs. 7,330,000 on refuse collection.

The use of large, widely spaced communal storage sites is usually a failure because the demand placed on the householder goes beyond his willingness to co-operate. Communal storage points should, therefore, be at frequent intervals. Madras, Bangalore and Manila provide fixed concrete receptacles with capacities between 100 and 500 litres on footways or verges at intervals of 50 to 200 metres. The objections to these have been stressed earlier, but they are fairly successful because they place a reasonable and acceptable duty on the residents, thus very little domestic wastes in thrown in the street.

Both the large masonry enclosure and the smaller concrete bin are inefficient in the use of manpower and vehicles. Wastes have to be removed by rake or shovel and and basket; it is a slow process and vehicle waiting time during the loading process is excessive. Vehicles employed on this work tend to interfere with other traffic in the stret. The following work performance havebeen recorded:

Delhi, masonry Enclosures	1.14 tonnes/man/day	7 tonnes/ vehicle/day.
Bangalore, concrete pipes	122 "	6 "

Drums of 200 litre capacity are far from an ideal solution, but the fact that two men can usually empty them directly into a vehicle with a low load line greately increases daily performance: probably to about 5 tonnes/ man/day and 10 tonnes/vehicle/day.

Block Collection:-

In this system, a collection vehicle travels a regular route at prescribed intervals, usually every two days or every three days, and it stops at every street interesection, where a bell is rung. At this signal the residents of all the streets leading from that intersection bring their wastes containers to th vehicle and hand them to the crew to be emptied. A crew of one or two men is adequate in number as they do not need to leave the vehicle.

Block collection should be operated frequently, otherwise the weight of wastes to be carried to the vehicle may be beyond the capacity of some of the residents. It has a significant advantage over a kerbside collection in that bines are not left out on the street for long periods.

This system is operated in Mexico City and during a study carried out by the Solid Wastes Division of the sub-secretariat for Environmental Protection the following data was collected. It represents the average of four routes:

Collection route, total length 2.74 Kms.

Number of stops on route 25

Average distance between stops 110 metres

Bins emptied per stop 33

Total bins emptied on route 858

Average load total weight 3,653 Kgs.

Dwellings on route 841

Average weight/dwelling 4.34 kg.

Total time for load 2 hours 27 mins.

Average travel time point to point 1.15 mins.

Average loading time per point 7.10 mins.

The daily performance achieved by this system is about 3.5 tonnes/man/day and 7.0 tonnes/vehicle/day.

Kerbaside Collection:-

This, like the block collection, requires a regular service and a fairly precise timetable. Residents must place their bins on the footway in advance of the collection time and remove them after they have been emptied. It is very important that bins of a standard type should be used, otherwise it is likely that wastes will be put out in improvised containers, such a cardoboard boxes, or even in loose heaps; when this occurs some of the wastes are inevitably scattered by animals and wind, thus increasing the work of street cleansing.

Kerbside collection is never entirely satisfactory. Problems include:-

- bins sorted through by scavengers,
- bins stolen,
- traffic accidents caused by bins rolling on the road,
- bins turned over ny goats or cattle,
- failure of the householder to retriever the bin quickly.

The worst example of this last problem is when the bins are kept permanently on the footway; this is not uncommon in high income residential areas of certain Asian cities.

However, kerbside collection is unavoidable with some types of house construction, and it is the cheapest method of house-to-house collection. When the rate of wastes generation is high and collection infrequent very high labour productivity can be achieved. For example, in one city in USA a one-man crew collects up to 10 tonnes/day-400 dwellings at an average of 25 kg/dwelling. In all developing countries, however, the wage-rate to vehicle-cost ratio would be much less than in USA and it would be profitable to employ a crew of at least four men. Productivity would also be reduced as the weight collected per dwelling would be much less .

Door-to-door Collection:-

This is the system in which the householder does no work: the collector enters the garden or courtyard, carries the bin to the vehicle, empties it, and returns it to its usual place. It is costly in labour because of the high proportion of working time spent walking in and out of premises and from one dwelling to the next, but it is the only really satisfactory system. A USA study showed that this system costs about twice that of kerbside collection, but this ratio would be greatly reduced in countries where labour cost is low.

The problem with door-to-door collection in developing countries is that vehicle productivity would be very much less than in Europe or USA if collection was at high frequency. High vehicle productivity must be the main aim of developing countries, thus door-to-door collection by the conventional western method of heavy motor vehicle and crew is very unlikely to be a viable system unless the interval between collections was extended to a week. This is unlikely to be acceptable in tropical countries as a principle and in any case the majority of dwellings in most cities need a daily collection (Or communal storage).

The broad conclusions that can be reached are as follows:

Communal storage systems based on manually portable containers probably offer the lowest collection cost.

Block collection at two-day intervals appears to offer a low collection cost and avoids all the problems that arise with communal storage or kerbside collection.

Door-to-door collection by a heavy motor vehicle and crew would be by far the most expensive system for a developing country if a daily service is

required. It ma/ be at an acceptble cost level in selected areas it a twice weekly service was adopted.

The conventional western approach may have to be ruled out. There are other effective possibilities. One of these is described in the next chapter.

Comparative productivity of Basic Systems:*

In the following table performance in terms of tonnes day and dwelling/day by men and cehicles are compared . Weight generated/dwelling/day is assumed to be 2 kg in every case, equivalent to 333 gms/person/day for a family of six people. This is about the current average for much of South East and Centra America (3 but generation in much of West Asia and North Africa may be twice this).

---

* Some figures are actual, others are writer's estimates.

Collection Method	Frequency of coln.	Kg/pickup point	Crew No.	Tonnes/ man/day	Tonnes/ veh/day	Dwellings/ man/day	Dwellings/ veh/day
Communal:				1.4	7.5	700	3,500
Enclosures	daily	3,000	5	1.2	6.0	600	3,000
Concrete bins	"	300	5	5.0	10.0	2,500	5,000
200 l drums	"	50	2	3.5	7.0	850	1,700
Block	2 days	4**	2	0.6	2.4	300	1,200
Kerbside	daily	2	4	1.8	7.[illegible]	250	1,000
	4days	7	4	2.8	11.[illegible]	200	800
	weekly	14	4	0.3	2.[illegible]	160	960
Door-to-door	daily	2	6	1.0	6.0	140	850
	4days	7	6	1.7	10.0	120	720
	Weekly	14	6				

The four most productive methods are as follows:

	Tonnes/ man/day	Tonnes/ vehicle/day
Communal 200-litre drums, daily	5.0	10.0
Block collection every 2 days	3.5	7.0
Communal masonry enclosures, daily	1.8	7.0
Kerbside collection every 4 days	1.4	7.0

Communal masonry enclosures, daily

Figures for weekly collection have not been included, having little practical significiance for most developing countries.

** per house.

SAMPLING AND ANALYSIS OF SOLID WASTES

Solid wastes is the term used to describe nonliquid waste material arising from domestic, trade, commercial, industrial, agricultural and mining activities and public services.

'Solid Wastes' is an extremely heterogeneous material comprising of a variety of things of various sizes containing dust, food wastes, packaging in the form of paper, metals, plastic or glass, discorded cloth and other textiles, ashes, garden wastes, wastes from construction operations, factory wastes rubber, fragment of bones, cotton wood, guase used for dressings etc. In certain areas where the sanitation facilities are inadequate it may contain night soil. In short, it contains everything man rejects or generated by his activities and what has to be removed from the place where he lives, works and moves for recreation and other purposes.

'Refuse' is synonymous with 'solid wastes' and generally indicates both putrescribe and non putrescribe material and consists of 'Garbage' 'Rubbish' and 'Ashes'.

<u>'Garbage'</u> is the putrescible animal and vegetable waste resulting from the handling preparation and consumption of food.

<u>Rubbish</u> comprises of conbrustible and non contrubstible materials such as paper card board cases, wood, glass, metal crokery, textiles and similar objects.

<u>Ashes</u> are residue of burning wood, coal, coke and other solid conbustible materials.

Analysis of solid wastes if of importance as a pre-requisite to methods of disposal such as sanitary landfill, composting or incineration.

A quantitative estimate of the total amount of material that is generated by a community and disposed of is again important to plan the infrastructure requirements of the management services, like the collection system transport, disposal facilities and manpower requirements.

Qualitative analysis gives projection of feasibility of disposal methods and project alternatives. Both the physical and chemical analysis assume relevance.

Analyses, however, accurate, is entirely dependent on the sample collected and can, therefore, have meaning only when a proper representative sample is collected.

The measurement of the total weight delivered to a disposal site can seldom give a correct indication of the wastes generated because there are considerable losses between the generation point at a household and the ultimate point of disposal.

The losses may be by salvage sold by the householder, salvage by scavengers and wastes disposed of by unauthorised means e.g. on unsued grounds and ditches at the generation point. Some losses due to salvage by collectors at the collection point is also likely to occur and some losses may be effected due to salvaging by disposal staff and free lance pickers.

The total quantity to be collected and disposed of can be estimated by one of the following methods:-

1. multiplying the average number of loads/day by the average volume/load and converting to weight basis by using an average density obtained by sampling.
2. Sample vehicle weightings using a weighbridge and the average multiplied by the total number of loads/day.
3. Weighing of every load on a weigh bridge at the disposal site.

The last method is obviously the accurate method.

Sometimes, it may be necessary to determine the amount of wastes generated when it is necessary to find out the volume required for storage of domestic wastes or estimate the recyling potential of the wastes.

Since the cycle of domestic activity varies through out the week, it is necessary to obtain samples that precisely cover one week. The variations that can occur is exemplified in the following table. Quantity of refuse ikg/head/day in a week for a typical town in India.

Day	SUN	MON	TUES	WED	THURS	FRI	SAT
Qty.	0.36	0.30	0.26	0.25	0.25	0.26	0.27

(0.5 to 1.5kg/capita in other countries maximum being In USA).

There is a wide range of wastes generation depending upon the socio-economic groups and dwelling types. Variations exists among single, multiple low rise and multiple high rise dwelling units and again on low medium and high socio-economic groups and shop and office wastes. The slums, bustees and semi-rural areas will have to be also in the classification.

The minimum size of a sample is 200 kg for similar dwellings falling into a single classification(NCERT suggests a 100 kg sample).

The minimum number of samples of 200 kg. ..r required would be about 12 and preferably by 20. If 12 such classified groups are not available, more than one sample should be collected from the largest group or groups.

Based on the above requirements of 12 sample/day, and assuming a per capita contribution of 0.35 kg. and 6 members for every unit, about 100 dwellings will have to be covered for each classification to give 200 kg/sample and a total of 7200 persons or 1200 dwellings will have to be covered to estimate total wastes of a city.

The total weight and volume generated could be calculated by using a suitable multiplier e.g. if a sample is taken from 600 persons in a group and the number belonging to this group in the city is 60,000 the multiplier would be 100.

It is necessary to supply every dwelling with a plastic bag for the period of the test. The wastes collected on the first day is generally discarded and collections from the 2nd to 8th day will represent a week's production. Each day the filled bag is collected and a new beg is handed over The bag is labelled appropirately with respect to the classification and taken to the depot where material from each classification is weighed.

For many purposes like deciding on the capacity and requirement of collection vehicles and the methods of refuse disposal, samples can be taken from the community containers directly. This requires only the collection of 12 samples of 200 kg. on a daily basis from areas which represent the selected socio-economic group and trade commercial andmarket sources. While collecting from storage bins samples should be taken from various points at various depths to make up 200 kg.

The density of samples collected from community containers is higher than collected at sources b ecause the density increases at each stage of handling. This is partly due to - removal of high constituents such as paper and also by compaction

of material at low level by pressure by wieht of wastes above and lastly by gradual filling up of interstices by dust.

Physical analysis gives the following information.

1. Density of wastes
2. Proportion of salvageable constituents.
3. Proportions of other constituents.
4. Proportion that can be incorporated in compost.
5. Combutible proportion.
6. Graded particle size.

Three or four analyses over a period of a year to cover the seasonal variations and the effect of climatic and food production cycle has to be carriedout.

Samples should be analysed within 2 hrs. of collection to minimum errors due to moisture loss.

Samples are taken in standard wooden box of 500 litres 100 (1m long x 1m high x 0.5m width). Smaller boxes could be used but the minimum volume should be 1l. A strong batten should be bolted on each wide to facilitate lifting of the box. The box is filled with a shovel, the contents should not be compressed but the box should be rocked back and forth three times during filling. The box is then weighed and the density found out.

This material is transferred to a sorting tables. The surface of the table is formed by a wire mesh of 50mm so that all material below this size falls through it. From the material retained on the table, the vegetable purtrescible wastes are left behind and all other constituents are picked out and put in a marked container for subsequent weighing. When sorting out of the oversize material is furnished, the table is sheken to ensure that everything below 60mm has fallen through. The wastes remaining on the table is vegetable-putrescrible over 50mm.

The matter which has fallen to the ground is now shovelled up and passed over a hand screen of 100 mm mesh. The wastes remaining on this screen is now hand sorted until vegetable putrescrible matter remains, this is 10mm-50mm size.

The material which has gone through 10mm screen can be seperated into iner and organic matter by moisture and ignition tests.

(The NEERI procedure suggest spreading out the entire material and dividing into 4 cuadrants, two opposite quadrants being mixed and the process repeated until a 12.5 kg sample obtained from 100 kg original sample).

After the physical analysis, the materials like metals, plastics, rubber etc. are neglected and moisture determined on the crude sample.

A sample of about 3 kg is air dried and finely ground and passed through a fine sieve of 4mm pore size. The sample is analysed for -

1. Moisture
2. Organic matter
3. Carbon
4. Nitrogen
5. Phosphorus as $P2^{05}$
6. Pottassium as $K2^{0}$
7. PH

Moisture place 500kg of sample in a tray in an electric hot air even overnight at $100^{0}C$. Cool in a dessicater and weighth. Report percentage loss in weighth as moisture. Analysis done in triplicate.

Organic matter: Place 100 kg of dried sample in a weighted silica dish and heat slowly in an electrical furnace to about, $700^{0}C$ for 30 min. If muffle furnace is not available, heating can be done over a Runsen Burner until the dish becomes dull red for 30 mn. or more. Cool the dish in a dessicator; weight and report percentage loss in weight as organic matter.

Carbon: Total carbon can be estimated by conbusting in a tabular furnace and absorbing CO_2 evolved and estimation of CO_2. But for routine purposes, the carbon figure can be obtained by dividing the percent organic matter by a factor of 1.724.

Total Nitrogen. Estimated by digesting the sample with Conc H2SO4 in presence of a catalyst and salicyclic acid. The clear liquid is neutralised by Na OH and titrated with bouic acid.

Phosphosrous: Organic matter is burnt off at a low frame after moitening sample with $Mg(NO_3)$ 2 and ethyl. Achohol, and then moistrned with 20 ml of water and 15 ml conc.Hcl and covered with watch glass and digested for 2 hrs. The solution is diluted to 150 ml and 100 ml is taken and precipitated by Ammonium molybdate solution. The precipitate is dissvolved in an excess of standard alkali and excess alkali is titrated. The P205 can be computed from the titne value.

Potassium 25 to 50 gm of sample is slowly heated on a silica basin until charring and then transferred to a muffle furnace for 30 min. to about $550^{0}C$.

Cool the dish add 40 ml dil Hcl (1:1). Place on a water bath and digest for 20 to 30 min. Remove cover and rinse with mlHNO_3 and evaporate to dryness. Continue heating for ½ to 1 hr. and then place in a hot air oeven for 1 hr. at 110°C.

Moisten dried salt with 10 ml dil Hcl; add a further 50 ml of water and keep on water bath until all salts are in solution filter and makeup the sample to 500ml.

Take an aliquot of 100 ml and use the method of estimation with perchiloric acid as potassium perchlorate precipitate or laternatively.

Use flame photometric method.

PH Make a suspension of 5 gm of well ground sample in 50 ml of distilled water. Keep suspension for ½ hr with occasional stirring. PH is determined by PH meter, PH indicator or PH paper.

It is likely that changes occur in the physical characteirstics of wastes from the following causes:

1. a rising standard of living increases production of solid wastes particularly constituents other than vegetable putrescible.
2. Changes in packaging technology and retail distribution methods tend to increase packaging material and volume per capita.
3. changes in domestic fuels e.g. a reduction in the use of solid fuel could cause a fall in ash content and reduction in weigh per capita.

In cities where annual analysis have been carried out for 15 years or more, changes of this kind appear on a graph as a smooth curve from which itis usually possible to entrapolate analyses several years ahead.

Analyses are made as part of feasibility studies for solid wastes disposal such as composting and incineration.

Range of values:

1.	Weight generated per day	250 to 1000 g/cap/d
2.	Density	100 kg/cum to 600 kg/cum
3.	Volume	½ litre to 10 litres/cap/d
4.	Veg.putrescrible matter	20% to 75%
5.	Inert matter	5% to 40%
6.	Paper	2% to 60%
7.	Glass	0 to 10%
8.	Metals	0 to 15%

Solid wastes is not expected to contain any intestinal parasites unless feecal matter is also collected. Where there is absence of sewerage system, there is likelihood of Ascaris and Trichuris appearing in the wastes.

NEERI carried out analysis of solid wastes in 33 cities in 1972:

1. The fine earth content ranges from 17% in Calicut to 77% in Bikaner. This high amount is due to the strong wind that blows from sand and earthy matter in the arid region.
2. There was a vide variation in the organic content of thesamples more than half the sample had values of 30 to 50%.
3. Paper content varies from 1 to 10% and in general ranged from 2 to 5%.
4. Plastics rarely exceeded 2% and in 82% samples was less than 1%.
5. Glass was less than 1% in 90% of samples and never exceeded 2%.

6. Density of sample ranged from 330 to 560 kg/cum/ in 85% of samples. Density values were higher in rainy season than in summer because of high moisture.

7. organic content were between 10 to 30% in 85. 9% of samples.

8. In 80% of the sample the N.P.K. in the decomposable fraction ranged from 0.4 to 0.6%, 0.3 to 0.5% and 0.3 to 0.8%.

9. Calorific value ranged from 770 to 2845 BTO/1b.

Analysis of Solid Wastes from cities in India - NEERI 1972

1. **Refuse Density**

Name of city	Winter Kg/M3	Summer Kg/M3	Monsoon Kg/M3
Bangalore	376.6	405.118	-
Patna	309	490.0	-
Allahabad	349.0	429.0	431.22
Baroda	496.11	480.0	390.0
Delhi	402.0	453.1	412.0
Hyderabad	342.0	410.0	354.0
Kanpur	640.0	647.5	684.8
Madras	271.0	314.0	403.0

II. PHYSICAL ANALYSIS OF CITY REFUSE

Name of City	Season	Paper	Rubber & Leather	Plastics	Rags	Wood	Metals	Glass	Coal	Crockery	Earthenware, stones & Bricks	Total Compostable matter	Fine Earth
Bangalore	Winter	1.08	0.11	0.38	0.58	0.14	0.25	0.24	0.69	0.45	1.42	42.59	52.06
	Summer	2.75	0.08	0.26	0.91	0.07	0.36	0.18	0.15	0.21	0.95	65.07	29.11
Patna	Winter	3.71	0.25	0.16	2.42	0.56	0.07	0.06	9.84	0.02	7.07	25.21	50.03
	Summer	2.29	0.89	0.24	3.89	0.62	0.47	0.24	6.58	0.01	7.25	21.27	56.34
Allahabad	Winter	2.96	0.17	0.17	3.42	2.64	0.24	0.34	2.45	0.87	7.98	43.52	34.46
	Summer	3.39	0.56	0.67	2.37	1.31	0.38	0.47	3.71	0.37	8.15	39.51	39.19
	Monsoon	5.13	1.12	1.22	2.05	1.10	1.05	0.36	4.58	0.22	5.41	50.49	32.23
Baroda	Winter	3.15	0.43	0.35	2.29	1.37	1.13	0.19	1.83	0.61	8.52	32.65	47.25
	Summer	2.03	0.16	0.34	3.01	1.99	0.49	0.48	0.61	1.29	6.98	43.10	39.36
	Monsoon	8.27	0.33	0.22	4.65	9.79	0.18	0.09	0.16	0.11	4.86	42.00	29.80
Delhi	Winter	8.20	1.73	0.66	5.31	0.59	0.71	0.32	7.82	0.05	6.43	43.14	24.96
	Summer	7.85	1.31	1.56	6.75	1.26	1.91	1.11	1.47	–	11.24	30.89	34.36
	Monsoon	2.83	0.77	0.33	2.04	1.06	1.02	0.29	3.39	0.34	9.15	32.22	49.16
Hyderabad	Winter	5.76	0.49	0.70	4.80	2.77	0.95	1.06	1.93	1.48	8.20	37.83	34.50
	Summer	4.31	0.88	0.45	2.10	0.88	0.21	0.60	6.16	0.16	10.13	24.04	49.62
	Monsoon	4.37	0.84	1.36	2.69	1.66	2.51	1.14	0.46	0.46	8.71	50.51	23.03
Kanpur	Winter	3.25	0.70	0.57	3.00	0.51	0.40	0.61	0.58	0.58	4.27	43.22	38.41
	Summer	3.38	1.52	0.75	3.85	1.47	0.72	0.27	0.92	0.92	12.97	30.51	39.21
	Monsoon	2.28	0.37	0.53	1.48	1.32	0.24	0.25	0.15	0.15	3.07	40.53	60.91
Madras	Winter	9.86	0.46	1.58	6.60	1.74	1.32	1.44	0.00	0.00	5.21	45.30	23.22
	Summer	4.72	0.59	0.54	3.39	1.59	0.72	1.00	0.36	0.36	5.74	48.01	29.13
	Monsoon	8.93	0.34	0.52	4.60	0.47	0.81	0.46	0.06	0.06	3.11	50.61	29.63

III. Chemical Analysis of cities refuse

Name of city	Sample	Moisture %	PH	organic matter (%)	Carbon (%)	Nitrogen (%)	Phosphorus as F20 (%)	Potassium as K20 (3)	C/N ratio	MCV in RTU/lb
Bangalore	Summer	43.29	8.63	19.33	10.74	0.60	0.92	0.90	17.69	11.46
	Winter	25.00	8.68	21.03	11.71	0.49	0.70	1.31	18.01	14.71
Patna	Summer	13.53	9.07	16.31	9.05	0.55	0.80	0.63	16.45	966.9
	Winter	14.26	7.83	11.96	6.78	0.56	0.75	0.84	12.07	1305.41
Allahabad	Summer	11.09	8.48	19.38	11.25	0.619	0.408	0.553	18.16	1323.36
	Winter	16.86	8.54	17.17	9.96	0.414	0.584	0.843	24.05	1318.79
	Monsoon	21.72	8.11	13.12	7.61	0.526	0.625	0.581	14.46	1287.62
Baroda	Summer	19.99	8.61	22.06	12.45	0.613	0.545	0.449	20.32	1250.70
	Winter	15.78	7.94	21.97	12.20	0.715	0.790	0.672	17.05	1414.02
	Monsoon	29.92	8.33	19.39	10.77	0.586	0.462	0.453	18.37	1585.79
Delhi	Summer	27.42	7.68	24.50	13.57	0.510	0.560	0.510	26.60	2431.92
	Winter	38.39	7.56	35.77	20.41	0.770	0.933	0.762	26.52	2845.16
	Monsoon	14.40	8.29	15.00	8.33	0.509	0.640	0.513	16.36	1286.52
Hyderabad	Summer	6.392	8.54	26.60	17.40	0.610	0.502	0.681	28.50	2512.4
	Winter	14.899	8.09	37.69	19.31	0.650	0.640	0.587	39.69	2499.3
	Monsoon	12.899	8.68	23.45	12.80	0.5300	0.624	0.572	34.18	2074.5
Kanpur	Summer	12.56	8.31	20.91	12.13	0.609	0.651	0.828	19.92	1272.75
	Winter	21.64	7.91	23.50	13.63	0.495	0.835	0.616	27.53	1422.57
	Monsoon	21.49	8.41	18.62	10.80	0.579	0.506	0.466	18.65	1139.5
Madras	Summer	27.35	7.52	31.32	14.72	0.559	0.454	0.725	26.325	2067.74
	Winter	38.30	7.67	34.75	15.38	0.572	0.569	0.940	26.88	1863.64
	Monsoon	40.25	7.36	23.06	13.03	0.598	0.402	0.620	21.70	1838.92

Transportation of Solid Wastes -
A Case Study of Delhi

Rakesh Gupta

Suppose there are n localities in a city where the refuse is collected at various points and is transported to m disposal sites that are located at the periphery of the city. Also, we know the distance a truck loaded with refuse has to travel for dumping garbage to the disposal site (one way). Let a_i be the number of truck load garbage generated in the locality i and b_j be the capacity of the disposal site j. We may well assume that the capacity of the disposal site is enough to take the total generated garbage.

$$\sum_{i=1}^{n} a_i \leqslant \sum_{j=1}^{m}$$

If we transport x_{ij} number of trucks from ith locality to the jth disposal site, the total distance travelled by trucks in the city for dumping the garbage at the disposal sites is:

$$Z = \sum_{i=1}^{n} \sum_{j=1}^{m} x_{ij} \quad d_{ij}$$

Where d_{ij} is the distance between the ith locality and the jth disposal sites.

Now our problem is to choose those x_{ij} which satisfy the following restrictions, and minimize, Z, the restrictions being:

$$x_{ij} \geqslant 0, \; i = 1 \ldots n; \quad i=1, \ldots m$$

(as we cannot transport negative quantities)

and

(1) $$\sum_{j=1}^{m} x_{ij} = ai, \; i=1, \ldots n$$

(i.e. we transport all the garbage from each locality

(2) $$\sum_{1x1}^{n} x_{ij} = b_j, \; j=1, \ldots m$$

(each disposal site swallows exactl the number of trucks as its capacity)*

Now this is a simple linear programming problem and is known as transportation problem. For solving such problems, the initial feasible solution can be obtained by (i) North-West Corner Rule, (ii) Matrix Minima or (iii) Vogel's Method.

Before proceeding to find an initial basic feasible solution to our problem let us define the following:

<u>Feasible Solution:</u>

A set of individual allocations which satisfy the constraints of the problem is called a feasible solution i.e. which simultaneously remove the refuse generated from the zones.

* If the total capacity of disposal site is more than the total generation in all the zones than by creating an artificial zone whose generation can be taken as the access capacity of the disposal site, the solution can be obtained using the simplex method.

Independent Allocation:

The allocations of a feasible solution are said to be independent if it is not possible to increase or decrease any individual allocation without either changing its positions in an allocation array or violating the limitations on the surpluses at the zones or capacities at the dumping sites.

Basic Feasible Solution:

A feasible solution is said to be a basic feasible solution if it has exactly (m+n-1) allocations in an m zones and n dumping sites problem.

Optimal Solution:

A basic feasible solution is said to be an optimal solution if the distance covered by it is minimum.

Methods of finding Initial Basic Feasible Solution

1) North-West Corner Rule

In this method we allocate the maximum possible number of trucks either from the origins (column total) or the destinations (row total). In Table 2., we thus allocate 48 units from column 1 to the cell (1,1). Now we are left with 79 surplus units against the first row's total. Of that, 46 units from column 2 are allocated to cell (1,2), the remaining 33 being given to cell (1,3). But still there are 4 units left from column 3 to be assisgned which are allocated to cell (2,3). In column 4 there are 27 units which are allocated to cell (2,4). Similarly, all the units in column 5 and 6 are given to cells

(2,5) and (2,6), respectively. Total of all the allocated cells in the second row is 100 units and as such no surplus is being left in that row. In the similar fashion we can allocate units in the remaining rows. The initial basic feasible solution obtained through this method is given in Table 3.4.

Matrix Minima

In this method we assign the maximum possible number of trucks in a row or column of a cell where the distance is least. For example in the entire matrix, the minimum distance is 4.27 km in cell (3,8). As such, all the 30 units of row are allocated to this cell. Next cell is (2,2) where the distance is 5.84 km. Here we can allocate all the 46 units of column 2. After completing these two cells, the minimum distance is 6.12 km in cell (1,1), where we can allocate all the 48 units from column, 1. In this process we can go on selecting the next minimum cell and allocate maximum units given in each row or column (Table 3.)

Vogel's Approximation Method

This is a heuristic method which provides an optimal solution or very near to optimum solution. Following steps are followed to obtain the solution:

Step I : Fvaulate a penalty for each row (column) by substracting the smallest distance element in the row (column) from the next smallest distance element in the same row (column).

Step II : Identify the row or column with the largest penality, breaking ties arbitrarily. Allocate as much as possible

to the cell with the least distance in the selected row or column. Adjust the supply and demand and cross out the satisfied row or column. If a row and column are satisfied simultaneously, only one of them is crossed out and the remaining row (column) is assigned a zero supply (demand). Any row or column with zero supply or demand should not be used in computing future penalties.

Step III : (a) If exactly one row or one colum remains uncrossed out, stop.

(b) If only one row (column) with positive supply (demand) remains uncrossed out, determine the basic variables in the row (column) by the least distance method.

(c) If all uncrossed out rows and columns have (assigned) zero supply and demand, determine the zero basic variables by the least distance method, stop.

(d) Otherwise, recompute the penalties for the uncrossed out rows and columns and then go to step II. (Notic that the rows and columns with assigned zero supply and demand should not be used in computing these penalties). The initial basic feasible solution obtained by the Vogel's Approximation Method is shown in Table 4

Now shall solve our transportation problem using Simplex Method where the initial feasible solution is obtained by the Vogel's Approximation Method. Generally, it is observed that this method gives the initial fesible solution very near to the optim and with much less number of iterations the optim l solution c n be obtained as compared to other ones.

Initial Feasible Solution Using Vogel's Approximation Method:

Let us denote the row penalities by R_i , i = 1,2,3,4 and column penalities by C_j, j = 1,2,3,4,5,6,7,8,9,10. Using Step I of the method we calculate R_i's and C_j 's for our transportation problem. In our case

$R_1 = 1.27$,	$R_2 = 2.79$,	$R_3 = 4.15$,	$R_4 - 5.89$
$C_1 = 4.35$,	$C_2 = 7.98$,	$C_2 = 2.90$,	$C_4 = 10.54$, $C_5 = 7.40$
$C_6 = 2.53$,	$C_7 = 4.25$,	$C_8 = 9.42$,	$C_9 = 14.55$, $C_{10} = 1.1$

In Step II we choose the maximum amongst all Ri 's and C_j 's. In our case it is $C_9 = 14.55$. This shows that first of all we have to make maximum allowable allocation in this column to the minimum distance cell. The minimum distance cell in this column is 8.42 so allocate all the 4 trucks to this cell i.e. all the four trucks load from the Najafgarh Zone to the Tilak Nagar disposal site as it can swallow all the four trucks. Now the remaining capacity of this zone is 26. Since all the refuse from the Najafgarh Zone has been allocated, the distance matrix is reduced by one column. Now again we use Step I and calculate R_i's and C_j's. The new R_i's and C_j's are:

$R_1 = 1.27$ $R_2 = 2.79$, $R_3 = 4.42$, $R_4 = 5.89$,

$C_1 = 4.35$ $C_2 = 7.98$, $C_3 = 2.90$, $C_4 = 10.54$, $C_5 = 7.40$

$C_6 = 2.53$, $C_7 = 4.26$, $C_8 = 9.42$, $C_{10} = 1.16$.

The maximum of R_i's and C_j's is $C_4 = 10.54$. In this column we have 27 trucks load of refuse tobe transported. Now the minimum distance cell in this column is 7.39 so we allocate all the 27 trucks of this zone to the Ring Road disposal site as it can swallow all the 27 trucks and the remaining capacity of the disposal site is 100 trucks load. In this way all the refuse from the New Delhi Zone has been transported to the Ring Road disposal site so our distance matrix is again reduced by one column i.e. C_4. Again claculate the R_i's and C_j's for the reduced matrix. The new R_i's and C_j's are:

$R_1 = 5.04$, $R_2 = 2.79$, $R_3 = 4.42$, $R_4 = 5.89$

$C_1 = 4.35$, $C_2 = 7.98$, $C_3 = 2.90$, $C_5 = 7.40$, $C_6 = 2.53$,

$C_7 = 4.26$, $C_8 = 9.42$, $C_{10} = 1.16$.

The maximum of R_i's and C_j's is $C_8 = 9.42$. In this zone 31 trucks load of garbage is generated and the nearest disposal site III is at a distance of 4.27 km but we cannot allocate all the 31 trucks to this disposal site as the remaining capacity of this site is 26, so we allocate only 26 trucks load of garbage to this disposal site.

In this way the cpacity of this disposal site is exhausted and therefore this row is deleted from the distance matrix.

Again we calculate R_i's and C_j's:

$R_1 = 5.04$, $R_2 = 2.79$, $R_4 = 5.89$,

$C_1 = 4.35$, $C_2 = 7.98$, $C_3 = 2.10$, $C_5 = 7.40$, $C_6 = 2.53$,

$C_7 = 4.26$, $C_8 = 7.61$, $C_{10} = 8.05$.

The maximum of R_i's and C_j's is $C_{10} = 8.05$. So column 10 is considered for making allocations. In this zone we have 6 trucks load of garbage and the minimum distance cell is 21.56 km thus we allocate the 6 trucks load garbage to the disposal site to Kailash Nagar. Since the whole garbage from this zone has been transported, so this column is also striked of and R_i's and C_j's are calculated for the reduced matrix.

$R_1 = 5.04$, $R_2 = 2.79$, $R_4 = 5.89$,

$C_1 = 4.35$, $C_2 = 7.98$, $C_3 = 2.10$, $C_5 = 7.40$, $C_6 = 2.53$,

$C_7 = 4.26$, $C_8 = 7.61$.

The maximum of R_i's and C_j's is $C_2 = 7.98$. So we allocate all the 46 trucks load of garbage from this zone to the disposal site at Majnu Ka Tilla as 5.84 is the minimum distance cell in this column. The remaining capacity of this disposal site is 54 and column 2 is delted from the distance cell in this column. The remaining capacity of this disposal site is 54 and column 2 is deleted from the distance matrix. Again we calculate R_1's and C_j's for the reduced matrix. The new R_i's and C_j's are:

$R_1 = 5.04$, $R_2 = 1.84$, $R_4 = 7.85$,
$C_1 = 4.35$, $C_3 = 2.10$, $C_5 = 7.40$, $C_6 = 2.53$,
$C_7 = 4.26$, $C_8 = 7.61$.

The maximum of R_i's and C_j's is $R_4 = 7.85$. This disposal site IV has a capacity of 34 and the minimum distance cell in this row is 7.93. But we can only allocate 29 trucks from this zone VII as it has only 29 trucks load of refuse generated. This we transport all the refuse from this zone to disposal site IV, the remaining capacity of the disposal site is 5 and column 7 goes off and we calculate R_i's and C_j's again for the reduced matrix.

$R_1 = 5.04$, $R_2 = 1.84$, $R_4 = 0.89$,
$C_1 = 4.35$, $C_3 = 2.10$, $C_5 = 7.40$, $C_6 = 2.53$, $C_8 = 7.61$.

Now in the zone VIII only 5 trucks load refuse is left which can be transported to the minimum distance cell 13.69 i.e. to the Majnu Ka Tilla disposal site. The remaining capacity of this disposal site is 49 and all the garbage from Zone VIII is transported in column VIII is also deleted and we calculate new R_i's and C_j's for the reduced matrix:

$R_1 = 5.04$, $R_2 = 1.84$, $R_4 = 0.89$,
$C_1 = 4.35$, $C_3 = 2.10$, $C_5 = 7.40$, $C_6 = 2.53$.

Now the maximum of R_i's and C_j's is $C_5 = 7.40$. So column V i.e. zone V is considered and the minimum distance cell in this zone is 17.07 which shows that from this zone all the 17 trucks should be transported to the Ring Road disposal site and the remaining capacity of this disposal site after disposing

17 trucks from zone V is 83 and Column V is also deleted from the distance matrix and the new R_i's and C_j's are:

$R_1 = 5.04$, $R_2 = 1.34$, $R_4 = 0.89$,

$C_1 = 4.35$, $C_3 = 2.10$, $C_6 = 2.53$.

The maximum of R_i's and C_j's is $R_1 = 5.04$ row I is considered and the minimum distance cell is 6.12 which is in column I. This zone has 48 trucks load of garbage generated and the disposal site has also the capacity to swallow these 48 trucks, so all the refuse generated in this zone is transported to the Ring Road disposal site whose remaining capacity after disposal of these 48 trucks load is 35 and column I is deleted from the distance matrix and the new R_i's and C_j's are:

$R_1 = 2.53$, $R_2 = 2.96$, $R_4 = 2.73$

$C_3 = 2.10$, $C_6 = 2.53$

The maximum of R_i's and C_j's is $R_2 = 2.96$ so row II is considered and the minimum distance cell is 8.63 which is in column VI (of the original distance matrix). This disposal site has the capacity of 49 trucks load only whereas in this zone VI the refuse generated is 52 trucks load, thus only 49 trucks load from this zone VI can be disposed in the disposal site at Majnu Ka Tilla. Therefore, we delete this row and calculate R_i's and C_j's for the reduced matrix:

$R_1 = 2.53$, $R_4 = 2.73$, $C_3 = 5.71$, $C_6 = 5.51$.

The maximum of R_i's and C_j's is $C_3 = 5.71$ so column II is considered where we have 37 trucks load refuse

and the minimum distance cell is 13.69 which lie in row I. This disposal site is left with 35 trucks load and as such we can transport 35 trucks load from this zone III to disposal site I. Now 2 trucks load left is to be sent to disposal site number II. Similarly 3 trucks load from zone VI are to be transported to the disposal site IV.

Table 3.6 gives the final allocations by this Vogel's approximation method which is considered as the initial feasible solution for the simplex method to be applied for obtaining the optimal solution to the problem.

To find the optimal solution with the help of simplex method, we have to choose U_i's and V_j's arbitrarily such that $U_i + V_j + dij = 0$, whenever xij belongs to the basic set and evaulate $\dot{d}ij = dij + U_i + V_j$ for the non basic xij. If $dij \geq 0$ o for all non basic xij's we have a minimum value of the objective function i.e. we have an optimal solution to our problem.

Table 3.6 gives the initial basic feasible solution to our allocation problem and now we proceed to choose U_i's V_j's such that $U_i + V_j + dij = 0$ whenever xij belongs to the basic feasible solution set.

If we choose $U_i = 0$, we can calculate $V_1 = -6.12$, $V_3 = -13.69$, $V_4 = -7.39$, $V_5 = -17.07$, with the help of $V_3 = -13.69$ we obtain $U_4 = -5.71$ and with the help of $U_4 = -5.71$ we get $V_{10} = -15.85$, $V_7 = -2.22$, $V_6 = -10.96$, with the help of $V_6 = -10.96$ we obtain $U_2 = 2.33$ and with $U_2 = 2.33$ we obtain $V_8 = -16.02$, $V_2 = -8.17$, with the help of $V_8 = -16.02$ we obtain $U_3 = 11.75$ and with the help of $U_3 = 11.75$ we obtain $V_9 = -20.17$.

Now we have to calculate $\dot{d}ij = dij + U_i + V_j$ for those cells which do not belong to the basic set. This way we calculate $d'_{12} = 9.60$ $d'_{16} = 0.20$, $d'_{17} = 10.42$, $d'_{18} = 6.20$, $d'_{19} = 13.70$, $d'_{10} = 7.32$, $d'_{21} = 6.08$, $d'_{23} = 0.23$, $d'_{24} = 16.82$, $d'_{25} = 16.82$, $d'_{27} = 12730$, $d'_{29} = 5.13$, $d'_{210} = -0.01$, $d'_{31} = 24.15$, $d'_{32} = 18.88$, $d'_{33} = 6.75$, $d'_{34} = 28.14$, $d'_{35} = 23.66$, $d'_{36} = 13.42$, $d'_{37} = 41.20$, $d'_{310} = 8.25$, $d'_{41} = 3.95$, $d'_{42} = -0.06$, $d'_{44} = 4.83$, $d'_{45} = 1.69$, $d'_{48} = -0.43$, $d'_{49} = 5.08$. (Table 5)

The only negative dij's are

$d'_{210} = -0.01$, $d'_{42} = -0.06$, $d'_{48} = -0.43$.

The most negative is $d'_{48} = -0.43$ which mens that X_{48} should come into the basic set. For bringing X_{48} into the basic set, we have to find the closed loope such that the basic feasibility is retained. As such we allocate 3 trucks to X_{48} and deallocate 3 trucks from X_{46} and allocate 3 more to X_{26} and deallocate 3 from X_{28}. With this, the number of independent allocations is $m + n - 1 = 4 + 10 - 1 = 13$, which shows that the basic feasibility is retained. Again we choose U_i's and V_j's in the same fashion and test that $\grave{d}ij = dij + U_i + V_j \geqslant 0$ for the non basic entries if we get all $\grave{d}ij \geqslant 0$, the optimal solution is achieved otherwise we repeat the process. After the second and third iterations (Table 6 and 7), it is only in the fourth iteration (Table 8), we find that all $\grave{d}ij = dij + Ui + Vj \geqslant 0$ for all the non basic entries and as such the optimum solution is achieved.

Thus it may be seen that when a scientific technique is applied, the efficiency of a system goes up. As stated earlier, the MCD is covering a total distance of about 7,000 km/day. In the case of the present exercise, the result obtained by the Simplex method is 2612.98 km/day (Table 8) which is one way travel to the disposal sites. The total distance covered is thus double of this figure i.e. 5225.96 km/day. Hence there is a reduction of about 25 per cent in the total distance.

Table - 1

Generation of Garbage in Delhi and distance from different zones to various dumping (landfill) sites.

	I	II	III	IV	V	VI	VII	VIII	IX		X
Site	City zone	Civil line zone	Karol Bagh zone	New Delhi zone	South Zone	Sadar Pahar-ganj zone	Shahdara Zone	West zone	Najaf-garh zone	Narela zone	Capacity of the land fill site
I. Ring Road	6.12	17.77	13.69	1.39	17.07	11.16	12.64	22.82	33.87	23.17	127
II. Manju-ka-Tilla	0.47	5.84	11.59	21.88	31.56	8.63	12.[illegible]9	13.69	22.97	13.51	100
III. Tilak Nagar	18.52	15.30	8.69	23.78	28.98	12.53	31.[illegible]7	4.27	8.42	12.35	30
IV. Kailash Nagar	15.78	13.82	19.10	17.93	24.47	16.67	7.93	21.30	30.96	21.56	40
Average Amount of refuse generated per day during July 1980 (in truck loads)	48	46	37	27	17	52	29	31	4	6	297

Table - 32

Initial Feasible Solution using North-West Corner Rule

	I	II	III	IV	V	VI	VII	VIII	IX	X	Total
Ring Road	48/ 6.12	46/ 17.77	33/ 13.69								127
Majnu-ka-tilla			4/ 11.59	27/ 21.88	17/ 31.56	52/ 8.63					100
Tilak Nagar						0/ 12.53	29/ 31.67	- 1/ 4.27			30
Kailash Nagar								30/ 21.30	4/ 30.96	6/ 21.56	40
Total (supply)	48	46	37	27	17	52	29	31	4	6	297

Feasible Solution by (N.W.C. Rule) (Total distance)

$$= 6.12\times 48 + 17.77\times 46 + 13.69\times 33 + 11.59\times 4 + 21.88\times 27 + 31.36\times 17 + 8.63\times 52 + 31.67\times 29 + 4.27\times 1 + 21.30\times 30 + 30.96\times 4 + 21.56\times 6 = 5000.25 \text{ kms/day.}$$

Table - 3

Initial Feasible Solution using Matrix Minims

	I	II	III	IV	V	VI	VII	VIII	IX	X	Total
Ring Road	48/ 6.12	17.77	35/ 13.69	27/ 7.39	17/ 17.07	11.16	12.64	22.22	33.87	23.17	127
Majnuka-Tilla	10.47	46/ 5.84	2/ 11.59	21.88	31.56	52/ 8.63	12.19	13.69	22.97	13.51	100
Tilak Nagar	18.[illegible]2	15.30	8.69	23.78	28.98	12.53	31.67	30/ 4.27	8.42	12.35	30
Kailash Nagar	15.78	13.82	19.40	17.93	24.47	16.67	29/ 7.93	1/ 21.[illegible]	4/ 3[illegible].96	6/ 21.56	40
Total	48	46	57	27	17	52	29	31	4	6	297

Matrix Minims:(TC) = 6.12x48 + 12.69x25 + 7.39x27 + 17.07x17
* 5.84x46 + 11.59x2 + 8.62x52 + 4.27x30
\+ 7.92x29 + 21.10x1 + 30.96x4 + 21.56x6 = 2635.78 kms/day

Table 4.- Initial Feasible Solution using Vogel's Approximation Method

Site \ Zone	I City Zone	II Civil lines Zone	III Karol Bagh Zone	IV New Delhi Zone	V South Zone	VI Sadar Pahar-ganj Zone	VII Shadara Zone	VIII West Zone	IX Najaf-garh Zone	X North Zone	Capactity of the land fill site.
I. Ring	48/ 6.12	17.77	35/ 13.69	27/ 7.39	17/ 17.07	11.16	12.64	22.22	33.87	23.17	127
II. Majnu-ka Rilla	10.47	46 5.84	11,59	21.88	31.56	49/ 8.63	12.19	5/ 13.69	22.97	13.51	100
III. Tilak Nagar	18.52	15.30	8.69	23.78	28.98	12.53	31.67	26/ 4.27	4/ 8.42	12.35	30
IV. Kailash Nagar	15.78	13.82	2/ 19.40	17.03	24.47	3/ 16.67	29/ 7.93	21.30	30.96	6/ 21.56	40
Average amount of generated per day (in truck loads, July 1980)	48	46	37	27	17	52	29	31	4	6	297

Total distance traveled/day = 48x6.12 + 35x13.69 + 27x7.39 + 17x17.07+46x5.84+49x8.63
+ 5x13.69+ 26x4. 27 + 4x8.42 + 2x19.40 + 3x16.67+29x7.93
+ 6x21.56=2615.43 kms/day.

TABLE - 5

First Iteration using Simplex Method

I. Site Zone	I City Zone	II Civil Lines Zone	III Karol Bagh Zone	IV New Delhi Zone	V South Zone	VI Sadar Pahar Ganj Zone	VII Shahadra Zone	VIII West Zone	IX Najaf-garh Zone	X Narela Zone	Capacity of land fill site	U_i
I. Ring Road	48/ 6.12	17.77 +9.60	35/ 13.69	27/ 7.39	17/ 17.07	11.16 +0.20	12.64 +10.42	22.22 +6.20	33.87 +13.70	23.17 +7.32	127	0
II. Majnu-ka-tilla	10.[illegible]7 +6.[illegible]8	46/ 5.84	11.59 +0.23	21.88 +16.82	31.56 +16.82	49/ 8.63	12.19 +12.30	5/ 1[illegible].69	22.97 +5.13	13.51 -.01	100	+2.33
III. Tilak Nagar	18.52 +24.15	15.3[illegible] +18.8[illegible]	8.69 +6.75	23.78 +28.14	28.98 +23.68	12.53 +13.32	31.67 +41.20	26/ 4.27	4/ 8.42	12.35 +8.25	30	+1.75
IV. Kailash Nagar	15.78	13.82	2/ 19.40	17.93	14.17	3/ 16.67	29/ 7.93	21.30	30.96	6/ 21.56	40	-5.71
Amount of refuse generated per day (in truck loads July1980)	48	46	37	27	17	52	29	31	4	6	297	
V_j	-6.12	-8.17	-13.69	-7.39	-17.07	-10.96	-2.22	-16.02	-20.17	-15.85		

Table -6.

Second Iteration Using Simplex Method

S. Site Zone	I City Zone	II Civil Line Zone	III Karol Bagh	IV New Delhi Zone	V South Zone	VI Sadar Pahar-ganj Zone	VII Shahdara Zone	VIII West Zone	IX Najafgarh-Zone	X Narela Zone	Capacity of Land fill site	U_i
I. Ring Road	48/		35/	27/	17/							
	6.12	17.77 +10.03	13.69	7.39	17.07	11.16 +0.63	12.64 +10.42	22.22 +6.63	33.87 +14.13	23.17 +7.32	127	0
II. Majnu-ka Tilla		46/				52/		2/				
	10.47 ~~+6~~.25	5.84	11.59 -0.20	21.88 +16.39	31.56 +16.39	8.63	12.19 +11.87	13.69	22.97 +5.13	13.51 - .44	100	+1.90
III. Tilak Nagar								26/	4/			
	18.52 +32.72	15.30 +18.68	8.69 +6.32	23.78 +27.71	28.98 +23.23	12.53 +13.32	31.67 +40.77	4.27	8.42	12.35 +7.82	30	+11.32
IV. Kailash Nagar			2/				29/	3/		6/		
	15.78 +3.95	13.82 +0.37	19.40	17.93 +4.83	24.47 +1.69	16.67 +0.43	7.93	21.30	30.96 +5.51	21.56	40	-5.71
Amount of refuse generated per day (in truck loads July 1980)	48	46	37	27	17	52	29	31	4	6	297	
Vj	-6.12	-7.74	-13.69	-7.39	-17.07	-10.53	-2.22	-15.59	-10.74	-15.85		

Table - 7.

Third Iternation Using Simplex Method

	I	II	III	IV	V	VI	VII	VIII	IX	X		
Site Zone	City Zone	Civil Line Zone	Karol Bagh Zone	New Delhi Zone	South Zone	Sadar Pahar-Ganj Zone	Shahdara Zone	West Zone	Najaf-garh Zone	Narela Zone	Capacity of Land fill site	U_i
I. Ring Road	48/ 6.12	17.77 +9.59	35/ 13.69	27/ 7.39	17/ 17.07	11.16 +0.19	12.64 +10.42	22.22 +6.63	33.87 +14.13	23.17 +7.31	127	0
II. Majnu-ka-Tilla	10.4[illegible] +6.6[illegible]	46/ 5.84	11.59 +0.24	21.88 +16.83	31.56 +16.83	52/ 8.63	12.19 +12.31	1[illegible].69 +[illegible].44	22.97 +5.57	2/ 13.51	100	+2.34
III. Tilak Nagar	18.52 +23.72	15.30 +18.44	8.69 +6.32	23.78 +27.71	28.98 +23.23	12.53 +12.88	31.67 +40.77	2/ 4.27	4/ 8.42	12.35	30	+11.32
IV. Kailash Nagar	15.78 +3.95	13.82 -.07	2/ 19.40	17.93 +6.83	24.47 + 1.69	16.67 -.01	29/ 7.93	6/ 21.30	30.96 +5.51	4/ 21.56	40	-5.71
Amount of refuse generated per day (in truck loads July 1980)	48	46	37	27	17	52	29	31	4	6	297	
Vj	-6.12	-8.18	-13.69	-7.39	-17.07	-10.07	-10.97	-2.22	-15.59	-19.74	+5.95	

— 21 —

Table - 8

Fourth and Final Iterations Using Simplex Method

Site Zone	I City Zone	II Civil Line Zone	III Karol Bagh Zone	IV New Delhi Zone	V South Zone	VI Sadar Pahar-Ganj Zone	VII Shahdara Zone	VIII West Zone	IX Najaf-garh	X Narela Zone	Capacity of land fill site	U_i
I. Ring Road	48/ 6.12	17.77 +9.66	35/ 13.69	27/ 7.39	17/ 17.07	11.16 +0.26	12.64 +10.42	22.22 +6.62	33.87 +14.13	23.17 +7.39	127	
II. Majnu-ka-Tilla	10.47 +6.62	42/ 5.84	11.59 +0.17	21.88 +16.76	21.56 +16.76	52/ 8.63	12.19 +12.24	13.39 + 0.37	22.97 +5.50	6/ 13.52	100	+2.27
III. Tilak Nagar	18.72 +23.72	15.30 +18.51	8.69 +6.32	23.78 +27.71	28.98 +23.23	12.53 +12.95	31.67 +40.77	26/ 4.27	4/ 8.42	12.35 +7.89	30	+11.32
IV. Kailash Nagar	15.78 +3.95	4/ 13.82	2/ 19.40	17.93 *4.83	24.47 *1.69	16.67 +0.06	29/ 7.93	5/ 21.30	30.96 +5.51	21.56 +0.07	40	-5.71
	48	46	37	27	17	52	29	31	4	6	297	
	-6.12	-8.11	-13.39	-7.39	-17.07	-10.90	-2.22	-15.59	-19.74	15.78		

IV. Since all $d_{ij} \geq 0$ in this iterration, we get the opinal solution to our problem. Total distance travelled per day = 2612.98 kms.

OPERATIONAL MECHANISM OF ENVIRONMENTAL SANITATION AND SOLID WASTES MANAGEMENT: PLANNING IMPLICATIONS AND PUBLIC RELATIONS

BY

D. N. Khurana*

Introduction

India is one of the most densely populated countries in the world. Major part of the population lives in rural India. Basing it on 1971 census, only 20 percent of the total population was living in 3119 urban areas. Due to Employment potential the urban areas have been an increasing source of rural to urban migration. To suport this, it may be stated that population of Delhi which was 17.44 lacs in 1951 increased to 26.59 lacs in 1961 to 40.66 lacs in 1971 and to 61.96 lacs in 1981 (estimated at start of census of 1981). This is resulting in haphazard growth of the metropolis. To arrest this, it is necessary to develop new areas as suburban/satellite towns.

On the major problems of environmental sanitation in urban areas in management of solid wastes which is generated due to activities of an individual and consists of ashes, house sweepings, kitchen, waste, vegetable waste, rotten fruits, road sweeping, cinder, pieces of wood, iron, glass, china were paper, plastic, rags etc, In developed countries even furniture, T.V. fridge and the like also form part of solid wastes. Quantum and type of solid wastes depend on economic position and standards of living of the society.

Part of solid wastes produced in recycleable like paper, plastic, glass, etc. and is picked up for recyclining by a section of the society. Solid Wastes, therefore, can be defined as rejects of the society; and in unsewered areas, even night soil forms part of solid wastes.

---

* Director-cum-Deputy Municipal Engineer, Conservancy & Sanitation Engineering Department of Municipal Corporation of Delhi.

Solid waste contains large percentage of organic/ putrifiable materials and due to climatic conditions in India its daily removal and scientific disposal is a must from health/aesthetic point of view.

Solid waste is also generated by various industries/ institutions which is required to be managed by the management of industries.

Imperative: requirements of solid waste management thus need to be kept in view by planners/local authorities, while planning new town, small and medium town and also for extension of existing townships and metropolitan areas.

Magnitude of Problems: For proper assessment of organisational. equipment and disposal requirements of solid wastes, it is necessary to assess the quantity and quality of solid wastes generated and which will have to be handled/managed for a new development. There is very large variation in quanity. The quality is not only different in various cities but also various in different parts of the same citi. This variation is due to:

a) Variation in economic status of inhabitants of various towns and reas of the same town/city; and

b) Variation in activities.

That is why the generation of wastes varies from 250 grs. to 1000 grs. per capita. Even the density of garbage has also large variations due to reasons given above and it varies from 100 kg. per cum. to 600 k.g. per cum.

Administrative Set-up:

Solid Waste Management is generally controlled by Health Officers assisted by sanitation staff. Govt, of India considering importance of the subject appointed a committee to

go into the problems of solid waste management and make recommendations for effective management of solid wastes under the Charimanship of Shri B. Sivaraman, Vice- Chairman, National Commission on Agriculture and the Member, Planning Commission. This committee submitted its report in 1975. One of the recommendations of this committee on administrative set up is reproduced below:-

Recommendation No. 7.

" The services of the public cleaning, machanical transportation and proper disposal of urban wastes should be put under unified control of a qualified public health engineer supported by qualified junior staff in different disciplines. To begin with, all local authorities in cities with population over one-lakh should implement this suggestion".

It may be mentioned that solid waste management is be controlled by Engineers in certain municipal Corporations like Bomay, Calcutta and Delhi. Pattern of staffing / hardstick is yet to be worked out as is prevalent for usual Engineering work.

Short-term stratedy for human exceurta disppsal. :

The necessity of disposal of human excerte by water-
torne system needs no empahasis but due to financial restraints
and time required for laying sewers, water lines, and sewage
and time required for laying sewers, water lines, and sewage
treatment plants, it is not possible to provide sewage
treatment plants, it is not possible to provide sewage
systems every where, Cent percent area of the metropolies is even not sewered till today due to restraints mentioned above. It is, therefore, desirable that to arrest migration to urban areas, the suburban towns be laid out and allowed to be habited after providing minimum basic services. The sewers can be provided later on. The disposal of human

excreta can be through "pour flush latrine" which can be connected to sewars as and shon that facility is available. This type of latrine has not sequatting pan with a trap having a water stal of about 20 mm to 25mm and can be flushed with water used for and cleaning. The excreta is discharged in to one of the two pits provided as per requirements based on number of users. The other pit is utilized after the first is completely full. The first pit is allowed to remain covered for about 18-20 months during which the excrete gets converted into compost and can be excavated and re-used when needed. The compost thus dug out can be utilized in fields. This will also avoid manual handling of excrsta.

This system will also reduce the requirement of water in the first instance, which is one of the basic necessities for towns.

The above suggestions can also be implemented even for stopping unauthorised sale of plots in suburbs of metropolis and may help in solving in problem of haphazard growth.

COLLECTION OF SOLID WASTE

Source and collection of Solid Waste

Source of solid wastes can be i) industrial units ii) commercial/institutional complexes iii) household iv) read side sweeping

Solid wastes generated by (i) and (ii) above is generally managed by owners of the industries/organizers.

Solid wastes generated by households is delivered by customary/private safai karamcharis to collection centras provided by the local authorities System of door-to-door collection has not yet developed in India and is not being dealt with here.

Road side sweeping is the responsibility of the local authorities. These sweepings were carted by the safai karamcharis still recent past as head loads to collection centres. But this system is being changed and safair karamcharis are now utilizing wheel barrows for cartage of road side sweeping at least in Delhi Municipal Corporation. The wheel barrows are generally stored on road side, after the day's work is complete, by a safai karamchari and space is required for proper storage of these. It will be desirable to provide an office for Assistance Sanitary Inspector/ Sanitary Inspector in the area which can also provide for storage of wheel berrows, stores for daily consumption items etc. etc. and can also work as a liaison office for the proper up keep of the area and to keep contact with the public. Number of such units will be dependent on many factors: one of which is the strength of staff both workers/ supervisory. Yardstick adopted in Municipal Corporation of Delhi for sanitation staff is as under:-

(1) Yardstick for road sweeping:

(a) Congested area - One safair Karamchari for 2322.5 sq. mtrs (25,000 sq. ft)

(b) Medium areas - One safai karamchari for 4645 sq. mtrs (50,000 sq. fit)

(c) Open areas- one safair karamchari for 9290 sq. mtrs (1,00,000 sq. ft)

(2) Yardstick for open drains:

(a) Shallow drains: One safair karamchari for 1067 mtrs (3500 fts)

(b) Deep drains carrying sullage - one safair karamchari for 762 mtrs (2500 rfts)

(c) Sullage drains: One safair karamchari for 305 mtrs (1,000 rfts)

(b) Storm water drains: One safair karamchari for 1600 mtrs (5,280 rfts).

The work of 20-25 safair karamcharis is supervised by one Asstt. Sanitary Inspector/Sanitary Guide. One Sanitary Inspector supervises the work of 4-6 A.S. is/Sanitary Guides and there are C S . Is and Sanitation Supdts for further supervision, control and guidance.

Planning Implications

(a) Office location: While Planning new areas, it will be appropriate that suitable sites are earmarked for offices of AS Is / S Is which should also provide for storage facility.

(b) Site for Quarters of Sanitation Staff: Site for quarters for Safair karmchar is be also earmarked in the layouts so that their place of work is not far off from the place of dwelling. More-over, this will help in avoiding segregation and give an impression of mixed colony as recommended by the committee appointed by the Government of India.

(c) Collection Centres: Refuse generated from various house-holds, institutions and road sweepings is collected at suitablly located collection centres. These collection centres carry different names in different areas and in Delhi we call covered collection centre a 'dalao' which as the capacity of 20-25 cum. and the open collection contre is called a dustbin having capacity of 2-3 cu.mts.

For proper up-keep of 'dalao' space for small store/ choukidar hut alongwith space for loading of refuse is also required.

Municipal Corporation of Delhi has developed a split level 'Dalao' where waste is collected at higher level and is loaded into a truck parked at lower level by just dragging It has helped in creating/better sanitation and has reduced the loading time as well as fatugue of the workers. This type of 'Dalao' can be provided where the feeding area is higher than the collection centre by about 1.3 mtrs to 1.5 mtrs so that split level can be achieved without any drainage problem at truck parking place.

Liftable bins can ne substitutes for small dust bins hut equipment for lifting it and emptying it into truck is yet to be developed. This will minimise double handling by the safai karamcharis.

Locations of dust bins and 'Dalaos' should be earmarked in the layouts plans at the planning stage because once houses come up, none permits construction of collection contres which perform a very important role in the solid wastes management. Locations should be such that vehicles get more accessible roads with proper easy approach as well as turning space, if needed.

Transportation:

Transportation of solid wastes to disposal sites is equally important as collection, Vehicles/equipment for this purpose have not yet been standardised. In small town local bodies, the waste is carted even by bullock carts. Till recent past only flat body trucks were /are being utilized for transportation. These were loaded/unloaded manually. Hence, the labour had to move along with the vehicle for which a cabin had to be provided alongwith the cabin of the driver. This reduced the carrying capacity of truck by

about 20 percent. Apart from that, the time taken for loading, unloading was/is more than the travel time and hence trucks are not utilized optimally. Improvement over this aspect has been achieved by utilizing trucks with tipping arrangements which saves the unloading time and space for cabin for workers is added to carrying capacity because all the workers are not needed to go with the vehicle for unloading.

Another equipment front-end-loader is now available for loading wastes into trucks. This reduces the loading time resulting in more trips by the vehicles. Though initial cost of this system is there but ultimately it is economical. This equipment of course can be used when sufficient spaco is available and collection centre is big anough where the equipment can move in.

Trolley tractor can be is being utilized for cartage of wastes from congested areas where trucks cannot enter. As tractor is not an equipment for long distance travel, transfer stations are needed for transhipment of wastes to fast moving vehicles especially where disposal sites are far off.

Equip out called carrier container has recently been introduced which is an improvement over tractor trolley system.

Certain other equipments like 'mobile compactors' and hydracon roll off tippers' have recently been developed. The former are being utilized in Bombay and Calcutta whereas the latter at Ludhiana. Before the equipment for transportation of solid waste is standardised, lot of research and development work will have to be done, keeping in view the tough task it has to do, because the equipment has to move over loose torrain at disposal sites.

Whatever type of equipment is utilized, maintenance of it will have to be taken care of. Committee appointed under the Chairmanship of Shri B Sivaraman had given its recommendations for workship for repair of transport vehicles, for their parking and for fueling arrangements for towns having a population of 3 lakhs.

At the time of initial planning, space for such workshop will have to be earmarked.

Where disposal sites are so located that transfer stations are needed, the sites for these will also have to be earmarked in the layouts.

Disposal:

Scientific disposal of solid wastes is one of the important aspects. Generally following methods of disposal are adopted:

1. Sanitary Landfill
2. Composting
3. Incineration

Sanitary landfill is the most common and cheap method. Of course, it consumes land and is sometime helpful in reclaiming lands also.

Solid waste containing organic matter when dumped gets converted into compost in due course of time. Certain local bodies have been selling this compost to farmers. Composting can be accelerated by mechanical arrangements and is gaining momentum. Machinery for composting is still to be standardised, especially with reference to its utility to small local bodies.

Compost cannot be considered as final disposal because all the wastes is not consumed by it and rejects of compost which vary from 40 to 60% have to be disposed of by landfill method. Composting as such can be considered a complement system of disposal to Sanitary Landfill.

Incineration: Incineration has not yet been adopted for solid wastes disposal, is general, in India. In certain hospitals, no doubt, the hospital wastes are disposed of by inciner ation. Residue of icineration, of course, has to be disposed of.

Planning Implications: Site for disposal of solid wastes be earmarked while planning new townships/extension of towns. keeping in view the following points:-

1. Wind direction prevailing
2. Ultimate use of filled up area
3. Risk of pollution transferred during filling
4. Ecology of the area
5. Risk to water source
6. Site be approachable by road capable to cater for traffic generated.
7. Suitably away from residential area
8. Should be so located that it does not create risk of bird strike on the air craft.

Public Relation: Public participation and cooperation is a must for keeping environment clean. It is, therefore, necessary to arouse the individual concerned for personal health and well being. For this purpose suitable posters/leaflets emphasing various aspects of keeping environment clean should be prepared be prepared and distributed to the house holders, school going children and others at their place of work. Films cinema slides can be prepared and shown to the public. Mass media can also be utilised to impart information and arouse individual concern on personal health and well being.

Assistance of people of influence such as religious leaders, elected representatives, trade union leaders, etc. should also be sought to gain the confidence and cooperation of the public.

To secure acceptance of public for new sites of collection centres/sisposal sites, it is necessary to educate them well in advance by spelling out the necessities/benefits which can accurue to the public of most hygienic and clean environment.

Summary:

1) To provide clean environment with low cost sanitation we may adopt 'pourflush latrine', till thewater borne disposal of excreta is available so that there is no delay in development of new towns large and small. This will also minimise the development expenditure in the initial stages.

2) Above type of excreta/disposal can also be adopted in hapharzard development in the vicinity of metropolis or big.

3) Appropriate sites should be earmarked for A.S. I. & S. Is Offices which should alsoprovide for storage facilities in the lay outs of the towns to be developed.

4) Sites for quarters for safai karamcharis be earmarked in the layouts so that their places of work is not far off from the places of dwelling. It will alsohelp in avoiding segregation and give an impression of mixedcolony as recommended by the Committee appointed by the Govt. of India.

5) Location of dust bins and 'Dalaos' (collection centres) be earmarked in the layout plans at the planning stage. Location should be such that vehicle get proper accessible and easy approach roads.

6) Space for workships, parking places for transportation vehicle and equipment be earmarked in the layouts.

7) Where disposal sites are solocated that transfer stations are needed sites for these be earmarked in the layouts.

8) Landfill sites be earmarked keeping in view the following points:

1. Wind direction prevailing
2. Ultimate use of filled up area
3. Risk of pollution transferred during filling
4. Ecology of the area
5. Risk of water source
6. Site be approachable by road capable to cater for traffic generated.
7. Suitably awayfrom residential area
8. Should be so_located that it does not create risk of bird strike on the air craft.

Public cooperation should be sought for better up keep of environmental sanitation.

....

TRANSPORTATION OF SOLID WASTE

IN

MUNICIPAL CORPORATION OF DELHI

By V.D. RAVIKUMAR S.E.(AUTO), MCD

1. INTRODUCTION:

Municipal Corporation of Delhi has to take care on the sanitation work of 1399 sq. Km. area of 1484 sq. Km. area of Delhi. Out of this 241 sq Km. is city area and 1158 Km. is rural area. City and urban area are thickly populated and enormous solid waste is genergted daily in these areas. These solid wastes are mainly collected from street and road cleanings, house hold wastes, trade wastes and slaughter wastes. On an average 2000 tons of solid waste is generated every day from these areas.

1.2 The solid wastes are collected every day from area and stored temporarily in various points earmarked. These storing points are called 'Dalaos' and 'Dust bins'. 'Dalao' is a big masonary covered structure where minimum 3 to 4 vehicles load can be accumulated. The 'dust bins' are of four types as given below:-

i)	Open Masonary Structure	1/4 to 1/2 truck load of refuse can be accumulated.
ii)	Steel Containers (Large)	These are having a capacity of approx 6 cum. and are carried by carrier container system.
iii)	Steel Containers (Small)	These are having a capacity of approx 3.5 cu.m. and are carried Dumper - Placer Vehicle.
iv)	Steel Containers (Large)	These are having 10 cu.m. capacity and are carried by Hydro-con roll off Tipper system.

1.3 The solid waste collected in various places are to be transported and disposed off in proper way daily since these wastes if allowed to remain in one place will become put rified and can pose a health hazard. Hence an organised transportation system works in the municipal corporation of Delhi to take up this task of transportation of solid waste daily.

2. TRANSPORTATION OF SOLID WASTE:

2.1 Resources

For the purpose of transportation, following vehicles/equipments are in use:-

i) Flat body trucks.
ii) Truck with tipping arrangement.
iii) Dumper-Placer
iv) Tractors.
v) Trolleys (2 wheeled & 4 wheeled)
vi) Container carries.
vii) Front and Loaders.
viii) Hydro-Con Roll off Tippers.

2.2 TRANSPORTATION BY VEHICLES:

Mostly, the loading of the solid waste is done mannually. The staff loading the solid waste are known as Lorry Beldars. Generally 4-6 Lorry Beldars are detailed with each vehicle and they load the solid waste into RR (Refuse Removal) Trucks from Dalaos/Dust bin. However in few places the Front and loaders are used for loading garbage in the R.R. Trucks. For those vehicles which are not having tipping arrangement the lorry beldars accompany the vehicle to the Land Fill site and unload mannually. There is a separate labour compartment provided in the cabin of the vehicle itself

where the lorry beldars can sit. In these vehicles which are having tipping arrangements, the solid waste is unloaded automatically by tipping arrangement. About 40% of the fleet strength are not having tipping arrangement and remaining 60% of fleet are with tipping arrangement.

2.3 CONTAINER CARRIER SYSTEM:

A two wheeled carrier is towed by an industrial/agricultural type of tractor. This carrier itself can pick up automatically the container placed in the area and carry it to the land fill site. This system itself is having a tipping arrangement and hence unloading is done automatically. These containers are having 6 cu.m. capacity and the tonnage of solid waste carried is 3 to 4.5 tons.

2.4 TRACTOR-TROLLEY SYSTEM:

In this system the tractor tows the 2 wheeled/4 wheeled trolleys to the landfill site and unloading is done by automatic tipping. This system is working mainly in congested areas viz Sadar Paharganj Zone (SPZ) and City Zone (CZ). In S.P. Zone, the two wheeled trolleys are used for carrying slaughter house waste. The trolleys are parked in the slaughter house itself and the solid waste is loaded mannually. The tractor tows the trolley and unload it at Sanitary Landfill. In City Zone the trolleys are kept in congested area/land where trucks cannot go. Here also tractor hauls the trolley and tipping is done by tipping arrangement.

2.5 DUMPER-PLACER OPERATION:

Steel containers of 3.5 cu.m. capacity are kept in one zone i.e. New Delhi South Zone. These bins are filled mannually. The vehicle with boom arrangement in the body, pick up the container from the area and places it an its body. Vehicle is driven to the land Fill Site and tipping is done hydraulically. Again the empty bin is brought back and placed automatically by the vehicle itself. From the type of the operation of the vehicle, it is known as Dumper placer.

2.6 SMALL TIPPER OPERATIONS

Matador vehicles, having tipping arrangement with approx. 3.5 cu.m. capacity are being used in zones. These are mainly used to transport the silt removed from Nallahs and small drains.

2.7 HYDRO-CON-ROLL OFF TIPPER:

This is special device amounted on vehicle, which can take a container loaded with refuse of 10 cu.m. capacity on to the chassis from ground level and then it is driven to Dumping Ground. Unloading is done by tipping and then the container is brought back and kept at site. This equipment is operated with one vehicle fitted with equipment and 8 bins of 10 cu.m. capacity. By using this equipment number of trips made by vehicle per shift can be easily doubled and may be even more depending upon the lead to the dumping site.

3. STANDARDIZATION:

At present all the Refuse Removal Vehicles are of a single make. The standardization has been done to achieve the following:-

a) Better inventory management.

b) Easy training of technical personnel

c) Interchangeability of parts/assys.

d) Better training of operational staff etc.

4. WORKSHOP FACILITIES:

The semi-mechanisation programme can only be successful, if there is a provision for better repair and maintenance. For this purpose Municipal Corporation of Delhi has got 1 Central Workshop and 6 Zonal Workshops. Load-chart showing the equipments/vehicles of each zone is given at Appendix 'A' A small-workshop is also located at Compost Plant, where recycling of the solid waste into agriculture mannure is being done.

4.2 CENTRAL WORKSHOP:

Central Workshop has got the following functions:-

i) Engine overhauling (for entire general wing vehicles)

ii) Bull Dozer Repairs.

iii) KarolBagh Zone refuse trucks repairs.

iv) Running a service station.

v) Light vehicles repairs.

vi) Running a patrol and diesel pump.

The zonal workshops send the engine assemblies to Central Workshop and as far as possible a replacement in given immediately. On an average 100 to 120 engines are overhauled in this section per year. For refuse removal vehicles, servicing programme is issued and effort is made to ensure that the R.R. Vehicles are serviced once a month at least.

4.3 ZONAL WORKSHOPS:

The Zonal Workshops undertake all type of jobs in a vehicle, except engine overhaul. Each Zonal Workshop is having required staff for all jobs viz welding, painting, Smithy, body repairs, electrical jobs etc. Each Zonal Workshop is having Assistant Engineer (Auto) or Foreman of Assistant Foreman.

4.4 EFFICIENCY:

The on road percentage of vehicle fluctuates between 80 to 85%.

5. SEMI-MECHANISATION PROGRAMME:

Mechanisation programme is in process and as a first stage few Front End Loaders are being pressed into service, especially in two places viz Azadpur Vegetable whole sale market, and Slaughter House. In those two places the mannual loading involves lots of manpower and also behicle utilisation becomes poor if mannual loading is done. Front and loaders with 600 kg/700kg. bucket capacity are being used. By using this equipment loading is done machanically and since the unloading is by tipping, most of the oouration becomes mechanised.

APPENDIX 'A'

ZONEWISE DISTRIBUTION OF RESOURCES

S.No.	Name of Zone	R.R. Trucks	Tractors	Trolly	Container Carrier	Dumper Placer	Matador	Loader	Dydrocon Roll off Tipper
1.	City Zone	34	9	5	-	-	3	4	-
2.	Sadar Paharganj Zone	40	9	5	-	-	1	5	-
3.	Karol Bagh Zone (Central Workshop)	28	2	-	1	-	1	1	1
4.	West Zone and Najafgarh Zone	30	3	-	3	-	1	1	-
5.	Civil Line Zone and Narela Zone	30	2	-	2	-	1	4	-
6.	Shahdara Zone	25	2	-	2	-	1	-	-
7.	New Delhi South Zone	36	2	-	-	2	1	1	-
8.	Compost Plant	8	6	-	6	-	1	5	2
	TOTAL	231	35	10	14	2	10	21	3

BUILDING AN 'INVENTORY CONTROL MODEL' FOR A CONSERVANCY DEPARTMENT

GIRISH K. MISRA*

The manager of a conservancy department in metropolis faces a problem that is worrying him. The total annual demand by his department for lubricants of a particular brand is 1,200 tins. This demand manifets itself at a rate per unit of time which (for the sake of simplicity) we assume to be constant and known in advance to the manager. In order to be able to meet the demand at the time when it manifests itself the manager must k ep a certain number of tins of lubricants in stock, and when his stock runs out he must order a new supply from the producers. The problem is that of the number of tins which he ought to order from the producers at one time, assuming that he wants to minimise his total operating costs.

One possible solution would be to order the whole, 1,200 tins at the beginning of the year on Ist January, say and to let this stock gradually run down (at the constant rate which it will be remembered we are assuming) until it reaches zero on 31 st December. The average number of tins in stock per unit of time, known as the average inventory, would then be 600 tins- i.e. one half of the order size. This is illustrated in Figure 1, where the down-ward-sloping line traces out the gradual decline in the quantity of tins hold in stock as the year proceeds from its beginning to its end.

---

* Professor of Urban Studies, Indian Institute of Public Administration, New Delhi.

If he adopted this procedure, the manage would have only one order to give to the producers each year, so that his total annual <u>ordering costs</u> would be very low. <u>Ordering costs</u> are the costs associated, for example, with issuing the purchase order, following it up if necessary taking receipt of the goods putting them into stock, and settling up with the producers. Clearly his total annual ordering costs will be greater, the greater is the number of orders he places during the year, so that with only one order they will be relatively low.

But his total annual <u>carrying costs</u> will then be relatively high. Carrying costs are the costs associated, for example, with the use of warehouse space to store goods, and with the locking up of money capital in the goods so stored.[1] Clearly his total annual carrying costs will be greater, the greater is the size of the order or orders he places, so that with a single order of 1,200 tins they will be relatively high.

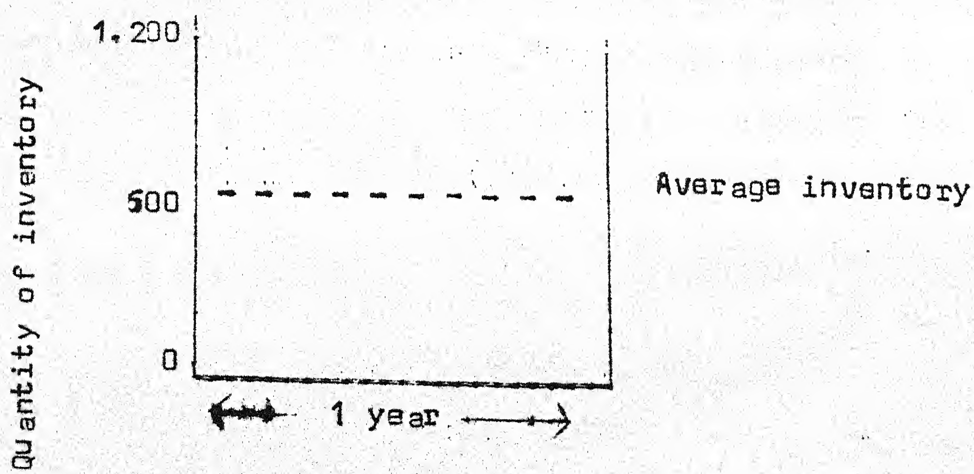

Figure 1

1. At bottom the costs involved here are that economists call 'opportunity cost' - e.g., the rent which <u>could have been earned</u> for the warehouse space if it had been used for some purpose other than that of storing the tins of lubricants, and the interest or profit which could have been earned on the money capital if had not been locked up in these stocks.

A large order size, then, may mean low total annual ordering costs, but at the same time, it means high total annual carrying

low total annual carrying costs. Suppose, for example, that the manager changed from one order of 1,200 tins per year to six orders of 200 tins. His total annual carrying costs would certainly then go down, since his average inventory would be reduced from 600 to 400 tins (see Figure 2). But at the same time since he would now be giving six times as many orders per year as he did before, his total annual ordering costs would be six times as great.[2]

The problem for the manager is to find the most profitable possible compromise between the two extremes i.e., to hit upon that particular order size which makes the sum of total annual carrying costs and total annual ordering costs as small as it can possibly be under the given circumstances. How can we help him to find this optimum order size?

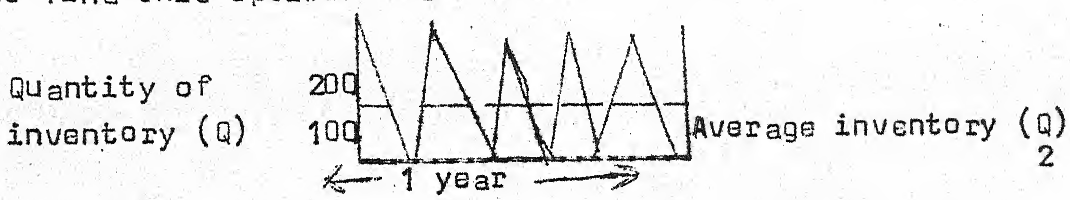

Figure 2

Let us feel our way towards a general solution of the problem on the besis of the particular case we hage just been considering. The manager's annual demand for lubricants, we have assumed, is 1,200 tins. Let us now assume further that each of these tins costs him Rs. 10/- that total annual carrying costs are lauays 20

---

2. This is on the assumption, which we are again making purely for the sake of simplicity, that the cost of giving an order remains the same whatever the size of the order of the frequency with which orders are made.

per cent of the money value of the average inventory carried during the year and that ordering costs are always Rs. 75/- per order. Given these figures, we can fairly easily work out the total annual carrying plus-ordering costs which will be associated with each of a number of possible order sizes.

This is done in Table 1 In column 1, under the heading order size' (which we symbolise by the letter (Q) we list a number of possible order sizes (i.e. values of (Q) ranging from 1,200 down to 100 On column 2 we list the number of orders per year which would be necessary, in the case of each of order sizes listed in column 1, to enable the conservancy department to meet the total annual demand of 1,200 tins. If the size of the order was 1,200 on order per year would be necessary; if it was 600 two would be necessary; and so on. If we call the total annual demand D, the number of orders per year will be D/Q.

In column 3 we give the money value of the average inventory which will he associated with each of the order siaes in column 1. The average inventory in <u>physical</u> terms will in each case be one-half of the order size (i.e. Q/2) In <u>money</u> terms it will be this physical number of tins multiplied by the assumed cost per tin of Rs. 10. If we call the cost per tin, C, the money value of the average inventory will be $\frac{Q}{2}$ (C).

In column 4 we give the total annual carrying costs, which we have assumed are always 20 per cent of the money value of the average inventory. If we call this percentage I, the total annual carrying costs will be $\frac{Q}{2}$(CI).

In column 5 we give the total annual ordering costs, which are simply the numbers of orders per year in column 2 multiplied by the assumed ordering costs of Rs. 1,200 per order. If we call ordering costs per orders total annual ordering costs will be $\frac{D}{Q}(S)$. Finally, in column 6 we add up the figures in columns 4 and 5 to obtain the total annual carrying-plus-ordering costs which will be associated with the various order sizes in column 1. In terms of our symbols, these total annual carr ying-plus-ordening costs will be $\frac{Q}{2}(CI) + \frac{D}{Q}(S)$.

The way in which the quantities in columns 4,5 and 6 behave as the order size increases can be seen more clearly if we graph the three functions concerned. This is done in Figure 3. The function relating total annual carrying costs to order size, it will be seen, is linear, proceeding upwards from left to right at a constant slope. The function relating total annual ordering costs to order size, on the other hand, is non-linear, proceeding downwards from left to right at an ever-decreasing slope. In the early stages, at the left- hand side of the diagram the total annual ordering costs function slopes downwards more steeply than the total annual carrying costs function slopes upwards, which indicates that at this stage the decrease in total annual ordering costs associated with a (small) increase in order size is greater than the increase in total annual carrying costs associated with it. And this in turn logically implies that total annual carrying-plus-ordering costs must be declining -which they indeed are at this stage, as can be seen both from the graph

Table- 1

Order Size	No. of orders placed per year $\frac{D}{Q}$	Money Value of Average Inventory $\frac{Q}{2}$ C	Total Annual Carrying Costs $\frac{Q}{2}$ (CI)	Total Annual Ordering Costs $\frac{D}{Q}$ (S)	Total Annual Carrying-Plus-Ordering Costs $\frac{Q}{2}(CI) + \frac{D}{Q}(S)$
1,200	1	6,000	1,200	75	1,275
600	2	3,000	600	150	750
400	3	2,000	400	225	625
300	4	1,500	300	300	600
200	6	1,000	200	450	650
150	8	750	150	600	750
120	10	600	120	750	870
100	12	500	100	900	1,000

D= Total Annual Demand: Q= order size; C= cost per tin of lubriciants:

I= Total annual carrying cost as 20% of the money value of the average inventory; and

S= Ordering cost per order.

(where the total annual carrying-plus-ordering costs function in the vertical sum of the other two) and from the table. But there eventually comes a point at which the downward slope of the total annual ordering costs function(which is constantly decreasing) comes into equality with the upward slope of the total annual carrying costs function, thereafter falling below it. It logically follows that at this point, total annual carrying-plus ordering costs must reach their minimum level, thereafter beginning to rise again.

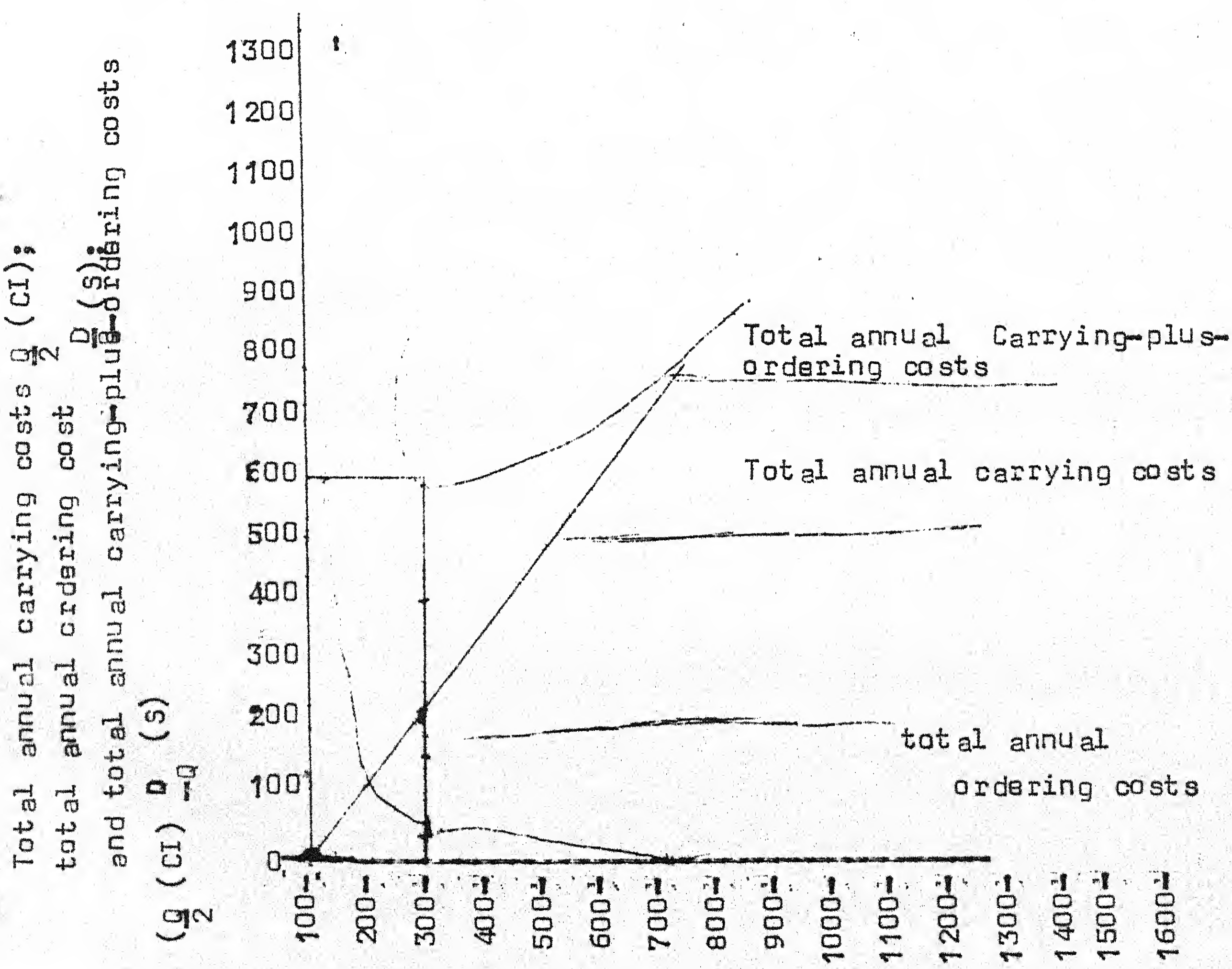

Figure- 3

In the particular case we are considering as can be seen both from the graph and from the table this crucial point is apparently reached when Q assumes a value of Rs. 300, which is associated with total annual carrying-plus -ordering costs of Rs. 600. Now the interesting thing here is that at this optimum order size of 300 total annual carrying costs are equal to total annual ordering costs. In other words, the optimum order size seems to be defined by the point of intersection of the total annual carrying costs curve and the total annual ordering costs curve.

....

COMPOSTING OF GARBAGE

A SEMI-MECHANISED PLANT FOR DELHI

B.B. NANDA
Deputy Municipal Engineer

Composting of Garbage

1. Introduction:

1.1 Mechanical composting of garbage is a natural process and not an artificial method as the impression the term of mechanical composting may convey. Farmers and gardners for many centuries have been practising composting by primitive methods. Night soil; vegetable matters, animal dung, refuse etc. are placed in piles and pits located in some convenient place and allowed to decompose, as conditions would permit until the material is ready for the soil or the farmers are ready to apply it to the land. This process involves little control, requires long period in pile to provide good humus, may or may not conserve maximum nitrogen and certainly does not provide sanitary treatment.

As per estimates of agricultural scientists about 4 years back the level of production of food grains was 125 million tonnes and about 12.5 millions tonnes of nutrients are taken out from the soil. The production of chemical fertilizers in the country is about 5 million tonnes. It means every year 7.5 million tonnes of nutrients are taken out extra from the soil. Recycling of organic wastes is as such a necessity.

It is believed that compost production can be so organised as to produce a significant amount of fertilizer at relatively lower cost in comparison to chemical fertilizers

and thus, increases the agricultural output and at the same time, economically solves a very pressing public health problem in urban areas.

Out of the several ways of disposing city refuse like, land fill method, incineration etc. compost manufacturing is the only method whereby a useful product particularly a product which is sure to enhance the agricultural output of our land is obtained.

1.2 <u>Two-fold Aspects of composting city Wastes:</u>

An improper disposal of refuse can give rise to growth of rodents and flies, causing unsightly nuisance, emit nasty odour and form a health hazard. The wastes dumped or burnt in the open and thrown into lakes or rivers are certainly going to risk human health through air and water pollution whereas the same could be converted into a national asset compost.

There are two important health aspects associated with the disposal and utilization of wastes. One is the high incidence of illness and death from faecal-borne diseases which result from insanitary disposal and utilization of waste. The other is the improved nutrition, an important factor in the prevention of diseases, which can be obtained when the wastes are returned to agriculture land to provide plant nutrients.

1.3 <u>Composting city wastes an important step for production of organic manure:</u>

The contribution of agriculture in accelerating our National economic growth has been very well realised now. Much emphasis is, therefore, being laid on the use of fertilizers in increasing agriculture production. It is, however,

observed that the intensive use of chemical fertilizers leads to deterioration in soil conditions and decreases its humus contents, unless it is counter balanced by the use of organic material such as compost.

It is found that in many parts of the world including parts of India, the soil has been over-worked depleting the organic matter in it and thereby reducing the productivity of the soil. Moreover, nitrogen and phosphorous compounds present in chemical fertilizers are better absorbed by plants if the soil is treated with organic manure. As such, organic manure are complimentary to chemical fertilizers. In fact, they are essential to increase the effectiveness of chemical fertilizers.

2. Composting Methods: Non-mechanical and Mechanical: Compost can be produced in a number of ways by using refuse. Broadly they may be classified under two general groups, non-mechanical and mechanical.

2.1 Non-mechanical methods:

Non-mechanical methods are employed where volume of refuse to be handled is small. In these methods readily compostable materials, such as, night soil, animal wastes, sewege-sludge and garbage and relatively stable organic matter, such as straw, leaves, municipal refuse and other types of stable wastes are kept in alternate layers on ground or in specially constructed pits and then turned regularly for a period of 8-12 weeks, stirred on ground for a further period of 4-6 weeks. After about 5-8 turnings and a total period of 4 months, the compost is ready for use.

2.2 Mechanical Method of composting:

The main disadvantages of traditional method of composting (non-mechanical method) are that it takes top long and the final product is not clean. Both these are taken care of by a mechanical compost plant, where the undesirable material such as metals, wood, glass, stones and the like are removed and the refuse, free from above items is converted into compost.

2.2 Anearobic composting:

Anearobic formentation develops when an insufficient amount of fair or air at all is in contract with the refuse. Carbon is for the major part transformed into methane gas and organic nitrogen is reduced to organic-acids and ammonia. Anearobic composting is a slow process and in practice several months are required for the transformation of household refuse. The amount of liberated heat is small and necessary temperatures are not obtained for destruction of pathogenic organism. For the reason that anaerobic composting liberates bad ordours, that the process is of long duration and that it is incapable of destroying all pathogenic organism and requires large areas, it is not suitable for metropolitan cities.

2.2.2 Aerobic Composting.

With sufficient supply of oxygen from air by turning and aeration, the waste material, decompose without liberating much odour and under sufficiently high temperature weed seeds and even the pathogenic organism destroyed. This is aerobic composting. The composting does not exceed a few weeks.

3. <u>Composting Fundamentals:</u>

The most important factors in mechanical composting operations are:

(i) segregation of refuse and salvegeable materials.

(ii) shredding the materials

(iii) Carbon-Nitrogenrelationship

(iv) Moisture-Contents.

(v) Temperature

(vi) Aeration

(vii) Climatic conditions

(viii) Fly control

(ix) Time required for composting

(x) Quality of compost

(xi) Economic aspect of composting

(i) <u>Segregation of refuse and salvageable materials:</u>
It is desirable that salvageable materials like rags, plastics, metals tin-cans etc. be removed from refuse. However, the experience has shown that in our country-these materials are already picked up from the collection points of refuse by the people earning their livelihood from these materials.

(ii) <u>Shredding of refuse:</u>
Shredding or grinding the material for composting can produce several beneficial results as the material is suscdptible to bactarial invasion through exposing a greater surface area to attack and destroying the natural resistance of vegetation to microbial invasion. The particle size of the material being composed is governed to some extent by the finished product requirement. The most desirable size of particles for composting is less than 2 inches (50mm). It has been observed that unlike the European refuse, which can contain a magazine or a

than 2 inches (50mm). It has been observed that unlike the European refuse, which can contain a magazine or a book or a large piece of meet, Indian refuse consist of the materials mostly having particle size below 50m.m.

Shredding of refuse is costly in terms of high capital cost involved hammer mill or a pulvarisor and in the terms of high energy cost in running these units, is therefore generally not necessary for plants in the country.

(iii) <u>carbon-Nitrogen relationship</u>:

The course of decomposition of organic matter is affected by the presence of carbon and nitrogen. The carbon-Nitrogen ratio represents the relative proportion in the two elements.

The decomposition of organic matter is brought about by living organism, which utilizes the carbon as a source of emergy and nitrogen along with carbon for building cell protopalsm. About 2/3rd of the carbon serves as a source of energy for the organism and is burnt up and respaired as CO_2 while the remaining carbon, approximately one third is combined with nitrogen in the living cells for building cell structure, c/N ratio is an important factor in composting. Its optimum value has been found between 20-30. A higher carbon-Nitrogen ratio will not only result in longer period for composting but will result in robbing the soil of nitrogen as the living micrabial cells making maximum use of available carbon by drawing on any available soil nitrogen in the proper proportion.

(iv) <u>Moisture Contents</u>:

Aerobic decomposition can proceed at any moisture content between 30% and 100% if adequate aeration can be provided. In practical aerobic composting a higher moisutre

content is avoided as water displaces air from the narrow space between the particles and thereby give rise to aneorobic conditions. . On the other hand, too low a moisture content deprives the organism of the water needed for their metabolism and consequently limit their activity. The optimum range of moisture content deprives the organism of the water needed for their metabolism and consequently limit their activity.

The optimum range of moisture contents in the refuse for aerobic composting is 40-60%.

(v) Temperature:

Proper-temperature is a very important factor in the aerobic composting. Considerable amount of heat is released by aerobic foremtnation and due to relatively good insultation properties of composting material, the heat of exothermic biological reaction develops high temperature. High temperatures are essential for the destruction of pathogenic organism and undesirable weed seeds, The optimum temperature range is between 50^0-70^0.

(vi) Aeration:

Aeration is necessary for aerobic composting in order to obtain the rapid buisance free decomposition. Turning the material is the most common method of aeration when composting is done in stacks. The most important consideration in turning compost apart from aeration is to ensure that the material on the outside of the pile is turned into the centre, where it will be subjected to high temperature. The frequency of turning and aeration depends upon the type of refuse

being composted at Delhi Compost plant the following turning sequencies being followed:-

Ist day - Stacking and adding of moisture.
5th day - Turning and spraying of moisture.
10th day - Turning and spraying of moisture.
15th day - Turning
20th day - Removal to process mill for screening.

(vii) Climatic Conditions:

Climatic conditions particularly temperature, wind and rainfall have not much significant effect on composting. However, during season of high rainfall, frequency of turning cycle is required to be increased to prevent an aerolic conditions.

(viii) Fly control:

One of the most important problem in composting is the control of flies.

The fly larvae in composting material may originate from eggs laid in the material at the place of collection or from eggs laid during the handling of the material is infested with eggs and larvae in various stages of development when it arrives at the compost plant. It is obvious, therefore, that the material must be prepared immediately for composting and placed in stacks where the high temperature and environmental conditions are favourable for the continued emergence of files.

Control of adult flies coming with the refuse is achieved by spraying 'Baygon' bates (insecticides) on specially built tents. Adult flies are instantneously killed when coming in touch with the insecticide.

(ix) Time required for composting:

The time required for satisfactory stabilization depends primarily upon

(a) the initial carbon-Nitrogen ratio

(b) the particle size (c) the maintenance of aerogibic decomposition and (d) the moisture content. Assuming that the moisture content is in the optimum range, that the compost is kept the aerobic and the particles of material are of such size as to be readily attacked by the organism present all of which factors can be controlled in the mechanical composting operation, the Carbon-Nitrogen ratio determines the time required for stabilization. Low Carbon-Nitrogen ratio materials are decomposed in the shortest time while high Carbon-Nitrogen ratio mate ials (C/N above 30) take longer time due to additional time required for recyling of nitrogen.

It has been observed that Indian garbage has Carbon-Nitrogen ratio as between 20 to 30. With this ratio time required for stabilising the compost has been observed about 20 days.

Quality of Compost:-

The nutrient value of compost varies wid ly depending upon the nature of the material being composted. If the initial material contains blood, salughter house wastes, conserved urine, garbage and sewege sludge, it will be richer in nitrogen and other nutrients than if it contains mainly straw, cane stalks, ash, dirt or municipal rubbish. The ranges of value, on a dry basis, in which the chemical characteristics of most finished compost generally lie are shown below:-

Substance	Percentage by weight
Organic matter	25-50
carbon	8-50
Nitrogen (as N)	0.4-3-5
Phasphorous as (P_2 05)	0.3-3.5
Pottasium (as $K_2$0)	0.5-1-3
Ash	20-65
Calcium (as coal)	1.5-7

The average N.P.K. values of one of the compost samples taken at the M.C.D. plant at Delhi were found as under:-

C%	N%	P%	K%	C/N ratio	PH
16.8	0.96	0.51	0.57	17.6	7.2

Economic Aspects of Composting:

No where in the world the composting of city wastes has been an economically viable proposition due to high capital cost and the recurring expenditure. The cost of production per tonne of compost has been estimated as Rs.80/- for the compost being prepared, at Delhi Plant. Out of this cost Rs.30/- per tonne is the cost componant for the interest being paid by the Corporation for the loan taken towards the capital cost of this plant. In case, the project of setting up of compost plant is treated as service development project and 100% grant-in-aid is provided, then the production cost is reduced to Rs.50/- per tonne. At this price it may be possible to avoid any loss.

4. CONTRIBUTION OF MUNICIPAL CORPORATION OF DELHI IN THE FIELD OF COMPOSTING.

The Municipal Corporation of Delhi conceived an idea of setting up of 200 tonnes a day capacity plant for composting citywastes as back as 1960. The proposal could not make much head way due to adverse ways and means position

of the corporation. The proposals was finally given a concrete shape in the year 1976, when sanction was accorded by the Govt. of India for setting up of a 150 tonnes/ day capacity plant at Delhi. The salient features of this plant are as under:-

4.1 150 tonnes/day (input) on single-shift basis.

4.2 Expected production-27,000/tonnes/year.

4.3 Total estimated cost Rs.79.58 lacs.

4.4 Total expenditure incurred Rs. 90.00 lacs

4.5 Estimated cost of production Rs.81.00 per tonne

4.6(a) Pattern of financing

Subsidy 1/3rd, given by the Govt. of India Rs.26.33 lacs.

4.6(b) Loan given by Delhi Admn., 2/3rd of estimated amount Rs.53.05 lacs.

In addition, a seperate scheme was also sanctioned by the Govt. of India, Ministry of Works ' Housing for an estimated amount of Rs.27.84 lacs for strengthening and improvement of infrastructure facilities for collection and transportation of refuse so as to maintain an uninterrupted supply of refuse at the compost Plant. The financial pattern of this scheme is as under:

(i) Subsidy given by the Ministry of Works & Housing - Rs.13.92 lacs

(ii) Loan given by Delhi Admn. - Rs.13.88 lacs

4.6.1 The Municipal Corporation has adopted Aerobic method of composting. Many unnecessary processes like perfermentation, shredding of refuse etc, have totally been eliminating, thus saving on the capital cost and operational cost. The broad outlines of the process adopted are as under:-

After the garbage is weighed at the receiption, it is unloaded by tipping trucks on the window pads. The window pad is a plain cement concrete platform without any walls etc. The window pile in a regular shape is formed through a 3M. wide Turning and Aerating machine. This machine picks up the garbage unloaded by tipping trucks and form at the back a window of 2.3M. wide and 1.5m height. Necessary moisture is also added by connecting a hose-pipe to the machine as may be necessary. Primary shredding to a certain extent is achieved by this machine through high speed beaters provided in the machine. Picking of certain amount of contraries like rags, plastics, larger pieces of stone, brick etc. is also done at this stage.

4.6.2 Each window, thus formed, is subsequently turned on 5th, 10th and 15th day through a set of another three machines having front widths as 2.3M, 1.8M. and 1.8M. Each of these machines is also provided with beater mechanism and water spreay arrangements. The garbage, thus composted, is then spread for drying on the ground for two days before the material is screened in the process mill.

It has been observed that aeration as well as size reduction of compostable matter is satisfactorily achieved.

4.6.3 The garbage so composted and dried is then fed into a hopper by means of a Hydraulic crane grab. The garbage through the hopper is then taken to a picking belt by means of an inclined convey or where picking of contraries is done by manual labour.

4.6.4 Garbage coming on the picking convey or falls on a vibratory screen. The screened material through this screen then falls on another belt, from where it passes

though a pebbles seperator specially designed. This seperator segregates the denser materials like glass pieces, stone pebbles etc. from the compost, and fine compost is collected through a seperate chute. It is worth mentioning here that this type of pebble seperator has been installed for the first time in this country in a mechanical composting plant. Through this seperator it has been possible to remove almost 100% of contraries like pebbles, glass pieces, china clay wares pieces., which are unwanted in the compost. This pebble seperator has been found to be very useful to have a very fine and product (fine compost).

4.7 <u>Equipments procured or being procured for the plant</u>:

4.7.1 Turning and aerating machines - 4 Nos.

4.7.2 At the process mill-one feeding hopper, one inclined belt conveyor, one number picking belf conveyor, one vibro screen, and one pebble seperator.

4.7.3 Equipment for material handling-2Nos. Cranes (one already procured and another is being procured) Three front-end-loaders, four trolleys, two nos. tractors.

4.7.4 In addition to the above, working facilities for maintenance of machinery and vehiles at the compost. Plant site have already been provided. For weighing, a self-recording type weigh-bridge has also been installed.

4.7.5 To meet the electric energy requirement, a subtation has been installed at the site.

4.7.6. For adding moisture into the garbage, arrangements have been made to store effluent coming from-adjoining dewage treatment plant. This affluent can be pumped into the distribution system through a pump.

4.8 <u>Following civil Works were undertaken at the site</u>:-

4.8.1 The land being water-logged, earth filing was done to reclaim the land.

4.8.2 A proper approach road of about 1½ km, length.

4.8.3 One time keeper's office.

4.8.4 One garbage block for parking the vehicles. Workshop facilities and stores also provided in this garbage block.

4.8.5 One Administrative block with a canteen for workers attached.

4.8.6 A window yard paved with concrete of the size 140 M.x 80 M.

4.8.7 Internal roads with proper drainage arrangements.

4.8.8 An underground tank for storage of effluent.

4.8.9 Concrete paved storage yard, provided for storage of compost.

4.8.10 In addition to all these civil works, intensive horticulture works also undertaken within and around the plant site for good environments.

4.9 <u>Administrative set-up for the plant:</u>

4.9.1 Transportation of garbage from the various collection sites will be placed under the control of the Manager compost plant. This has been done with a view that an uninterrupted flow of good quality garbage can be maintained at the plant site.

4.9.2 Operation and maintenance of the plant will also be under the charge of the Manager compost plant.

4.9.4 For sale of compost, the Municipal corporation has approached agricuture Department of Delhi Administration tohandle the job, as the corporation is not in direct touch with the farmers. However, much success in this direction has not yet been achieved.

4.10 <u>Expectation regarding production targets</u>:

The Corporation hopes to achieve the production target of about 27,000/- tonnes per year because of the simplicity of the design of the plant, rugged nature of the equipments selected and availability of good quality garbage in abundance. Fortunately, Delhi is an area of scanty rain fall and production is not likely to suffer during rainy season also. The production capacity of this plant can be doubled by working on two-shift basis. This can be done with the existing equipments. However, a sum of Rs.30 lacs will be needed for acquiring the adjoining piece of land, its development and construction of window platform. This can bring down the cost price of compost considerably. However, this step can only be taken after market is established for the disposal of the compost.

4.11 <u>Problems likely to be faced</u>: The problem which at this stage is causing concern is the sale of compost at least at no profit and no loss to the corporation. There appears to be demand for the compost in this country. As such selling of compost may not be a problem, provided suitable sale promotion measures are taken. However, the civic body is not going to get any remuneration on the sale, the production cost being high.
At present, the corporation is selling the compost to farmers at Rs.40/- per tonne F.O.R. plant site. In addition, only Rs.2/- per km. is being charged for the

single journey for transportation of the compost to the fields. It has been observed that with these two facilities, the demand for compost is developing. However, the farmer is not ready to pay Rs.80/- per tonne for the compost which is the cost of production.

5. <u>Reasons for slow progress in the field of Composting City Wastes:</u>

5.1 The Ministry of Agriculture and Irrigation launched a large scale programme of setting up of mechanical compost plants in selected cities during the 5th Five Year Plan. The programme envisaged to set up 35 compost plants in selected cities with a population of 31 lacs and above. As against this, 24 projects have been approved so far (including 4 projects, approved during 1978-79). Two plants, one each at Ahmedabad and Baroda, have already been commissioned. Plants at Bangalore and Calcutta are complete and are undergoing trial runs. Plants of Bombay, Delhi, Kanpur and Jaipur are under various stages of construction.

It can, thus, be seen that there had been an insignificant progress in the field of composting city wastes. Reasons for this slow growth are summarised as under:-

5.1.1 <u>Financing:</u> The setting up of mechanical-cum-compost plants involves large capital investments. The financial resources position of the various agencies like Municipal Corporation/Committees/Agro-Industries Corporation which undertake setting up of such plants, are generally not sound enough to meet the capital cost of these projects from their own resources. As an incentive for these organisations, the Ministry of Agriculture and Irrigation provides 33% subsidy towards capital cost of the plant, machinery and civil structure,

while remaining 67% of the capital cost is to be met by the Corporation/Committee either from their own resources or by raising loans from the financial institutions like banks etc. High rate of interest charged by banks, pushes the cost of production to the extent which is beyond the economic reach of an average farmer. When Compost is sold at a price lower than the cost of production, heavy losses are incurred in operation of the plant. The local authorities cannot bear the loss every year because of the poor ways and means position. The entire project cost as such should be provided as a grant by the Govt.

5.1.2 Economic Viability: At the time of preparation of project reports, most of the bodies which undertook this work envisaged that the proposal may be a profitable venture. However, this illusion was soon cleared, when some of the plants introduced the product in the market and were frustrated in their efforts to sell it at a profit. The experience of Ahmedabad plant in this direction is an example.

The Ahmedabad plant produced about 450 tonnes of compost during the year 1975-76, out of which it could sell only about 36 tonnes @ Rs.70/- per tonne.

Since there was no further offtake at this price, the Rs.25/- per tonne. So far this plant has incurred a loss of about Rs.25 lacs, starting from Oct.1976. This gloomy picture presented by some of the plants which have come into operation, also prevented many other corporations/Agro-Industries to take up this venture.

Most of the Plants have been located in big cities, having no appreciable cultivation belt in the vicinity. Transportations of compost to far-off distance adds to its cost thereby increasing the losses further. In places where the compost plants are being run by Municipal Corporations, the civic body, having no experience of marketing and having no direct link with the farmers, find difficulty in selling the product.

Being a new product, a prospective buyer is readily available. At national level or at the level of State Govt. steps should be taken to popularise the product. The corporations/Agro-Industries are not able to promote the sale of compost due to financial constraints. In addition, there are other factors like non-standardisation of the plants etc. suitable for our garbage.

6. <u>Steps needed for accelerating the compost movement:</u>

(i) The Municipal Corporation/local authorities should be provided 100% subsidy for setting up of compost plants.

(ii) The cost of operation and maintenance of these plants should be subsidised by the Govt./State Govts.

(iii) The Municipal Corporations/local authorities should not be charged cost of land by the Govt., State Govts/ Development Authorities at commercial rates, other infrastructure facilities such as electricity etc. should also be provided at non-commercial rates.

(iv) Publicity about compost at National and State level should be made.

(v) The marketing of compost should be the responsibility of the State Govts/Agro-Industries corporations at no profit and no loss basis to local authorities.

URBAN SOLID WASTE AS FERTILISER

BY

O.P. Vimal

URBAN solid wastes are a major source of land, water and air pollution, if expoited inefficiently. Use of these biodegradable materials as source of energy and fertiliser could help to meet the growing needs, consistent with the maintenance of helath and sanitary conditions. But, the whole, problem is be set with a number of limitations - local material, technological economic, organisational and fiscal.

This article aims at the discussing the prospects, problems and utilisation of these human hanitation wastes as a source of fertiliser. A knowledge about the characteristics of garbage is essential to decide the type of disposal methods that will be to be adopted keeping in view the growting concern over environmental pollution, the soaring cost of land in and around the cities and the sky rocketing cost of energy, there is an urgent need to consider these resides as not wastes but new resource materials.

Urban Solid Waste as Fertiliser

By

O. P. Vimal

ENERGY crisis, food shortage and environmental pollution are the main problems facing mankind.

These problems owe their origin to growing population, expanding urbanisation and rapid industrialisation. These recent developments have aroused concern regarding the 'quality of life' in the years to come. Under these fast changing conditions, it has become imperative, nay indispensable, to make critical appraisal of the 'needs' 'resources' and 'limiting factors/constraints' not only for the present but also for the future.

According to the estimates made by the National Commission on Agriculture, the population of India is likely to increase from 650 million during 1980-81 to about 935 million during 2000-2001 A. D., marking an increase of about 44 per cent during a period of 20 years only.

The estimated total foodgrain requirement at this future date will be about 225 million tonnes, an increase of about 69 per cent of comparison to this base year. In view of the fact that the per capita availability of arable aland is likely to decrease from 0.29 ha (1971) to 0.17 ha (2000 A.D.), the only alternative left is to double the yield per hectare. It is evident that to attain the food production target of 225 million tonnes during 2000-1001 the requirement of fertilisers will be

28.7 million tonnes. With an anticipated supply of 21.6 million tonnes of fertislier nutrients, the deficit will amount to about 7.1 million tonnes, which will have to be met though exploitation of locally available organic resources.

A glance at the fertiliser production and consumption pattern reveals that the shortfall has been significantly high during the period 1977-78 to 1981-82, the variations being (in thousand tonnes): N 913.3-1514.2 phosphate 196.7-387 and potash 506.2-676.2 Despite all efforts of the fertiliser industry, the country had to import fertilisers worth of Rs. 29.628.2 million during the same period to bridge this gap.

The energy requirements for the production of inorganic fertilisers are high; which very from 1400 kcal/kg nutrient for pottassium chloride to 15,600 kcal x = + 0 . The energy crisis has been mainly responsible for a steep hike in the price of fertiliser nutrients from 1972 - 73 to 1982-83 (as on 23rd May 1982), the per cent increase is as follows: N 33-75; phosphate 12.70 19.6; and ptash 82.4= 114.6 The high p- fixing capacity of some of the soils, particularly the laterite, red, black and coastal alluvium soils, and leaching of nitrate, and potash below the surface horizen in coarse-textured soils are the main factors contributing to low fertiliser-use effeiciency.

An assessment of the nutrient status of the soils indicate that about 95 per cent soils respond to nitrogen, 98 per cent to phosphorus and 62 per cent to potash. Thus, the low level of soild fertility

is one of the main constraints in boosting up agricultural productivity.

High yielding varieties exhibit their production p-otential only under optimum supply of nutrients, e.g. rice crop with a yield potential of about 5,000 kg/ha removes 107 kg No. 40 kg phosphate and 113 kg ptash. Deficiency of micro-nutrients, particularly that of zinc, is becoming quite widespread in many soils in India. The above facts emphasize the need to cast a fresh look at the local organic resources so far considered as 'waste'. Under such a situation efficient utilisation of urban wastes can help to solve not only the disposal problem but alsoprovide an inexhaustible, renewable source of humus and plant nutrients.

Availability and Characteristics of city garbage:

It is estimated that about 20 million tonnes of city garbage is generated annually in India. On the basis of population, the cities have been grouped into four categories. Out of the 33 cities studied, 20 cities recorded per capital values ranging between 0.15-0. 35 kg/day. The maximum per capita value recorded in a city was 0.481 kg/day in comparison to average values of 1.0 kg/day and 2.4 kg/day in Japan and the U.S. respectively. The total compostable portion in refuse from India ranges between 33-42 per cent, whereas in the western countries it ranges between 10-22 per cent. The chemical composition of the city compost shows that it can be used as a fertiliser for crop production.

The physical analysis of the city refuse from Delhi city given by Gurani is as follows (in per cent); vegetable matter

20.3, paper 5.8, rubber and leather 0.9plastics 0.5 rage 3.6, wood 0.5, metals 0.6, glass 0.3 earthen wares, stones and bricks 3.8, total compostable matter 57.4 Line reported the following compo nents of city refuse (in per cent) collected at the rate of 3000 tonnes/day in peninsular Malayasia: Kitchen refuse 63.7, paper and card board 11.7 glass and ceramics 2.5, metals 6.4 plastic and rubber 7.0 wood 6.5, was 1.3 and miscellaneous 0.9. Golueke observed that paper is the major source of cellulose in municipal refuse in the U.S. followed by wood and cotton texitiles.

Composting:

It is a biological process for converting solid wastes into a stable, humus-like product which finds use as a soil conditioner. It is a self-heating, thermophilic and an aerobic process which occurs nuturally in acumulations of biodegradable solid organic matter. Modern composting is aerobic and combines mesophilic and thermophilic terperatures. Keeping in view the bulky nature of city garbage, comp osting has become accept able both environmentally and agriculturally.

A survey conducted on the various aspects of garbage of 33 Indian cities revealed that the municipal authorities spent on an average nearly 10 per cent of their annual budget on solid wastes management, a majority of which was incurred on transportation.

Under such circumstances, composting of refuse was found to yield more revenue than the expenditure incurred.

These day, disposal of urban wastes in big cities by conventional composting methods is posing a serious problem due to increasing costs, unavailability of land for compost making, labour requirement for composting operations which involve human contact with filthy and obnoxious materials and marketing of compost. These problems result in the utilisation of this valuable waste in an unconomic and unhygienic manner.

Under these conditions, mechanised comp osting is the only alternative in big cities because it can be situated at a central location and in small compact areas, thus avoiding long haulage and constant search for new lands. Moreover, the other advantages accuring from mechanised compesting are: sanitary control with odur-proof devices, working in both dry and wet seasons, recovery of discarded materials like metal, glass and other non-compostable fractions and high grade compost quality in a very short time.

While discussing the UNIDO's experience on organic recycling in Asia, Maung stated that although urban composting can meet only a small portion of the country's fertiliser needs, it may provide the only readily available fertiliser. Through careful planning and organisation, ude of simple processing

techniques and equipments, it can provide aneconomic solution to the refuse disposal problem of towns and cities considtentwith a supply of valuable fertiliser to agriculturists in the vicinity.

Processing of city garbage into compost:

Compesting systems can be classified on the basis of exygen requirement, temperature and technological approach. There are 16 types of composting processes commonly in use: Bangalore (India), Cospari (Germany), Dano Bio-stabiliser (Europe) Earp-Thomas (Germany), Switzer Land, Italy), Fairfield-Hardy (U.S.). Fermascreen (England), Frzer-Eweson, Jersey (U.K., Thailand), Metrowaste (U.S.), Naturiser (U.S.), Riker, T.A. Grane (Japan), Tollemache (Spain, South Rhodesia), Triga (France, U.S.S.R. Argentina), Windrowing (U.S., Israel) and Van Maanen (U.S., Netherlands).

The principal operating processes of the modern, mechanised and authomated plants are as follows: i) Pre-sorting to remove bulky materials unsuitable for composting or salvaging, (ii) shredding the coarser components; iii) removing glass and metal fragments; iv) composting the organic material at acclerated rates in fully enclosed chambers for 1-3 days (including partial recirculation for seeding purposes) under controlled sorobio, moisture and temperature conditions v) completing the maturation

in windrows for a further period of 3-10 weeks to produce a stable, odour-free end-product, and vi) the addition of chemical fertilisers as required, either during or at the end of the process, to obtain the required fertiliser characteristics.

Egua pointed out that out of 35 plants, only 5 or 6 in operation in those cities of Japan where the unnecessary mixtures are almost completely sorted out from the kitchen garbage. The economic imbalance between the increasing wages and cheap prices of the products resulted into the closure of rest of the plants. From the studies conducted on three methods of aeration- a) turning, b) vacuum-induced ventilation, and c) pressure (forced air) ventilation by De Bertoldi, on the basis of thephysical, chemical microbiological and pathogenic data, observed that better results can be obtained with static composting systems than with a turning system.

After studying the changes in organic constituents of the compost it was condluded that maturing of the compost is not effected in piling the city refuse without turning and aeration. The inside of the widdrow remained anaerobic and some toxic substances are produced. Jongejan suggested windrowing/compacting as the most promising process which involves hand sorting of items in the refuse harmful to shredder, magnetic separation of ferrous content, and mixing grabge with sewage sludge.

Digestion or decomposition of city garbage is carried out in open windrows. Goluoke defined windrow methods as a continuous process, because wastes are applied at one end of the pile and compost is taken away from the other end. The length of windrow may be any, but its height should be exceed 1.5 metre and width 2.5 metre using natural aeration. With forced aeration, heap size depends on need to avoid overheating.

The time required for digestion depends on the intial C.N. ratio if proper moisture, particle size and aerobic conditions are maintained. Studies at the University of California revealed that approximately 11.13 and 21 days are required for composting of the refuse having CN. ratio 20,30-50 and 78 respectively. Lutz has described a fully enclosed waste treatment plant for co-composting of refuse and sludge.

Agricultural value:

Use of city compost pormotes soil aggregation and stablises soil structure. This improves the air-water relationships of soil, thus increasing the water retention capacity and encouraging extensive development of root system of plants. Hart while evaluating municipal compost as an erosion control residue, observed that it can be a good substitute for straw and manure over a 7 year period.

The erosion losses from small plots on a 30 per cent slope were reduced from 5.0 to 0.2 m^3 of soil per hectare per year when

60 tonnes of compost was applied as mulch. The physical determinations of the soil samples from fields incorp orated with non-segregated, non-comp ost solid waste made by Webber indicated an increase in the water-stable aggregates and a decrease in the bulk density with increments of solid wastes added.

The release of nutrients during the decompostion of urban compost in soil is similiar in effect to other manures. The continuous application of city compost for 4 years alone and in combination with chemical fertilisers showed an indrease in available) and K. Katyal and Sharma recorded significant increase in Zn and Cu contents of Indian soils by the application of city waste compost.

Garbage compost is used in all areas of crop growing and soil amelioration, that is in crop farming, grassland farming, horticulture, foresty land reclamation and the various fields of landscaping. However, the following three most important requirements concerning compost quality are to be considered:

a) an absence of substances injurious to man, crop or soil:

b) a high content of organic matter and plant nutrients and

c) a low content of useless substances like stones, slags, fragments, plastics etc. It improves not only the physical health of soils , but also provides netrients to the crops, resulting in better crop productivity.

Evaluation and study of the demonstrations by Duggan indicated that municipal compost gave positive yield response when used at 37.5-100.0t/ha. The most significant increase in to bacco yield resulted from compost application on heavy clay soils due to an improvement of its physical condition. Field demonstrations on wehat, oat, barely and rye have indicated that response had been most favourable when compost was incorporated at 37.5 to 75.0 t/ha into the soil.

Because of low nutrient contents of city compost, its fortification or entrichment with chemical fertilisers, sewerage sludge and microbial cultures was suggested for increasing the nutrient availability tocrop plants and thereby the crop productivity. Pillai and Vamadevan carried out experiments with an orano-mineral fertilizer having NPK in the ratio of 5-15.4 with 44 per cent comp ost as the base.

The application of this product at 80 kg N/ha increased grain yield of rice by 300 kg over 80 kg. N/ha application through urea alone. Vlamis and Williams reported significant increase in the yield of tomato, barley and lettuce by the application of sewage sludge and garbage compost.

Health aspects: Solid wastes generated in urban surroundings are contaminated by a wide variety of organisms-pathogenic or parastic on human beings and animals. With an increasing use of night soil and sewage sludge in combination with city refuse,

the significance of pathogen survial, fly breeding and their destruction during composting has assumed increased importance. The studies carried out at many places have shown the destruction of pathogens and flies during the thermophilic stage of composting.

The termal dealth points of some common pathogens and parasitics have been given by Gotass Salmonella typhosa: no growth beyond 46^0 C, death within 30 min. at 55-60^0 C, Shiglla Sp: death within 1 hr at 56^0; Escherichia coli: most dies within 1 hr at 55^0 C and within 15-20 min. At 60^{0}c; Entamoeba hystolytica cysts; death within a few minutes at 45^{0}C and within a few seconds at 55^{0}c: mycobacterium tuberculosis: within 15-20 min. at 66^0 C; Necator americanus: death within 50 min. at 45^0 C; and Ascaries lumbricoids eggs: death in less than 1 hr above 50^0 C;

Wiley and Westerberg studied the survival of pathens in compost and reported that only cerobic comp osting where a high temperature profile of 60 to 70^0 is obtained and retained for at least 3 fays could destroy these indicator organisms. More recently, studies carried by Nandakishore have shown that the pile bight and the degree of seration of windrows influenced significantly the temperature profiles of the comp ost piles.

The thermal death point of Salmonella typhimurium was found to be 65^0 C but an exposure at 50^{0}C for 24 hours was sufficient to obtain its complete kill when the raw material was inoculated.

The temperatures reached in aerobic composting are lethal to fly larvae and eggs. Care should, therefore, be taken to ensure that all portions of the windrow reach these temperatures so as to obtain a material clean from the public health point of view.

Environmental pollution:

At present, a greater proportion of the city garbage is dumped in low lying areas which becomes the major source of ground water pollution. The run-off from the refuse mass causes pollution of surface waters. The movement of such water through soil also results in soil pollution. The gases produced during the decomposition of city garbage under anaerobic conditions and incineration under aerobic conditions result in air pollution. Thus bio-degradation, leaching and volitilization of city garbage result in serious land, air and water pollution.

McGriff reported that accumulation of urban solid wastes increased the sediment load carried by streams, decreased groundwater recharge and promoted eutrophication resulting in degradation of water quality. The increase in PH, E.C. total soluble organic carbon and nautrally occuring metals like Fe in leachates was observed by Fuller, and an increase in hevy metals, endrin, lindane, methoxychlor, toxapone 2,4,5-TP exedding the toxis limits was recorded by Brown.

Studies carried out at MEERI, Nagpur on the concentration of pollutants in the leachates coming out of city garbage revealed that the quantities of chlorides, sulphates and hardness were much larger than those reported elsewhere. After about 4 months period, most of these parameters, except hardness decreased to the permissible limits.

Studies were made on the vertical migration of some nutrients in the soil after heavy application of municipal wastes by platzen. It was observed that application of refuse at 30 t/ha did not increase the content of chemicals namely alkanes, fatty acids and phthalate esters beyond toxic limits to plants. Fuller observed more rapid movement of poutants through soil when leachate has low P^H and higher concentration of total organic carbon, soluble common salts and some naturally occuring metals like iron.

The nitrate content in the inland waters was observed by Koepf. When leachates were used for growing soyabeans in sand culture, Menser observed that it resulted in an imblance in the proportion of nutrients causing stunted gruth of plants. King, observed increased levels of Zn, Cu, Pb and Cd in grain and stover of corn grown in soil treated with the city refuse.

To avoid the pollution of ground-water and toxicity of soil, a materialblance sheet needs to be prepared for varying rates and frequencies of applications of organic wastes. No

one method or technique of waste utilisation of is the answer to waste management in every location.

From this synoptic survey it is evident that urban solid waste can prove, a valuable resource material; but in order to make the sale of this product a feasible proposition, it is imperative to convert these bulky materhls-into high-analysis products using inorganic fertilisers, sewage sludge and microbial cultures. The combined use of organomineral fertilizers can only help to conserve energy, minimize environmental pollution, bridge the fertilizer gap, save foreign exchange as well as improve soil health. It is hoped that efficient exploitation of these biodegradable pollutants may provide inexhaustible and renewable resource materials for use in agriculture.

Improper soild waste disposal is a health hazard. Open dumping of refuse results in serious land, air and water pollution. To solve these problems, it is essential to recycle urban wastes in an efficient and safe manner, but resource recovery is beset with a number of constraints. This is illustrated by the role of non-comp ostable components. eg. metals can be easily recycled from industrial scrap but the present methods of making steel can tolerate only limited scrap input and thus the scrap recovered has low market value. Glass is easy to re-propose and can be used in many ways, but the raw materials for glass are available so abundantly that there does not seem to be any gain through hrecycling.

Although the residues of pyrolysis-combustible gas, tar and charcoal have economic value, yet these products have not found wide acceptance commercially, Most of the gas is used in supplying energy for the process itself. The tar is full of water and must be refined. The charcoal is full of glass and metals, which have to be separated prior to its use. This septerationmakes the charocal too expensive compared to wood, charcoal.

Because of the horizontal growth of cities, no land is available in big cities for dumping of refuse (even by sanitary-landfull methods). Non-availability of agricultural land in the vicinity of cities increases the cost of transportation of compost to the field. Local and traditional needs for FYM and farm compost limit the use of the compost prepared from city solid waste due to the influence of social customs and taboos; excreta have been regarded as something very abnoxious and highly polluting.

It is true that their biodgradation can be a source of disease and health problems, but right attitude to their potential value as a source of nutrients can help in devising methods to derive full benefits from them. The poor nutrient content and the non-unformity of refuse limit its use for composting.

The high cost of mechanical comp osting plants and the non-utilization of by products are mong the factors which make the process an uneconomic proposition. The most critical link in the process of composting is the segregation operation. Hand-sorting of garbage at the compost plant is tedious, expensive and insanitary. Detailed investigations are needed to evolve better seperation methods.

It is felt that if seperation of non-compostables could be achieved economically, composting could become an attractive method for resource recovery. Supply of compost at subsidised rates and its free transportation to farms may help to popularise this product. There is need for co-ordination between the civic bodies charged with solid waste management in cities and research organizations for the efficient recycling of wastes.

An ideal approach would be to find out a suitable method for spearating glass, metals, paper, wood plastics and other non-compostables from the putrescible compostable fraction. Glass and metal scrap can be recovered in original form. Materials having high heating value, such as paper, wood and plastics, should by pyrolysed for recovering energy, while the putrescible organic material should be processed through the mechanical composting plant for conversion into fertiliser.

The traditional method of urban composting is highly unscientific. Care is not taken to provide a balanced food and optimum environmental conditions for themicrobes to convert the wastes rapidly into good quality compost and to minimise leaching and volatilization losses. This calls for investigations on various aspects of the composting process in mechanical composting plants so as to handle in the shortest possible time huge heaps of refuse gathered everyday in the cities. The quality of the final products should be enriched with mineral fertilisers and microbial cultures, so as to make the setting up of mechanical composting plants economically viable. The high investment on complete mechanization of the compst plant coupled with the costs of repair and servicing emphasizes the need for setting up mini-mechanical compost plants which would be more appropriate under the socio-economic conditions prevailing in India.

Where it is not possible to recycle the whole quantity of refuse efficiently for energy and fertilizer, part of it can be disposed of around the cities through the use of sanitary land fill methods.

A number of other organic wastes are available in India from animals sheds, farms, fish and marine sources. These neglected materials, if exploited efficiently, could significantly help to meet the energy, fertilizer and material needs of the country of course with adequate attention to the over coming of pollution hazard.

THE TECHNOLOGY OF SOLID WASTE DISPOSAL

JOSE T. VILLATE*

KINDS, AMOUNTS OF SOLID WASTES

Cultural habits and economy considerations determine, in large part, the kinds and quantities of solid wastes produced in any given society. An example of a year-cound solid waste problem arising out of economies of scale is the production of manure from cattle feedlots. The prupose of the feedlots is to fatten young steers rapidly and prepare them for a nearby market. It has been caculated that a head of cattle produce 20 to 40 pounds of manure daily. Therefore, feedlot with a cattle population of 10,000, a fairly common number, may produce 200 or more tons of wet manure daily. It has been estimated that some 100 million cattle are being fattened on any given day, so manure production is high.

To the tons of cattle manure must be added the manure generated by the population of swine (60 million), turkeys (120 million), and chickens (450 million), which like cattle, are also raised in confined spaces.

An example arising out of new technology involving chemical engineering is the development of plastics of all kinds, that are used in packaging and manufacturing practices from the smallest merchant to the largest industrialist.

---

*Jose T. Villate is Associate Professor of Urban Systems at Florida International University.

Relatively inexpensive, at least until the recent increase in fuel prices, plastics can be convenient and durable. And it should be noted that the national average of plastics in municipal solid wastes is at about 2 percent and seems to be increasing.

Although accurate figures are difficult to obtain, the daily per capita production of solid wasted in the U.S. is seven to eight pounds. This amount represents only those solid wastes collected by municipal and private agencies and does not include agricultural and industrial wastes.

PRESENT DISPOSAL METHODS

Dumps. A dump is a land disposal site where solid wastes are deposited with no regard for public health, pollution consequences, or aestthetics. Dumps are often referred to as "open dumps" because the wastes are left uncovered. Very frequently, open dumps become buring dumps where the fires are spontaneous or purposely set in a typically unsuccessful attempt to reduce the volume of wastes and to control insects and rate.

Open and buring dumps are an unnecessary method of solid waste disposal. Dumps are health hazards that provide shelter and breeding grounds for mosquitoes. Flies and rate and contaminate surface and ground waters through two simple mechanisms. Wastes dumped in or near bodies of water can pollute the water directly. Rain or surface waters percolating

through the dumps leach out toxic and non-toxic substances from the wastes, carrying them into the ground water. Some of the reselts include imparting tastes and edors to the water, introducing toxic substances into the water, and possibly forming carcinogonic substances when the water is chlorinated for drinking purposes.

Unfortunately, in spite of their colossal environmental impact, open dumps seen to be the most common means of solid waste disposal. Many communities have never full assessed the costs of an open dump. When short-and long-term health effects, laundary and cleaning costs, and reduced real estate taxes are included, dumps are very expensive methods of solid waste disposal.

Landfills. One alternative to open dumps is the landfill. Landfills range from the most common kind, nothing more than "managed dumps" or "burial sites", to the kinds, which is a small minority, where established engineering principles, such as shredding and compeotion of the wastes, are applied.

A A true sanitary landfill, especially one in which the wastes are shredded, has many advantages. It can receive all kinds of solid wastes except hazardous ones, including a shredding step to permit a better compaction, represents an economical process, and in a way provides a final solution. Microbiological activity will convert an acrobically thebio-

degradable wastes into a humu-like substance, leaving only plastic and metals, if the latter have not been removed previously, Shredding converts the discarded glass into a said-like material which is incorporated into the soil. A true sanitary landfill offers a final bonus: with a little imagination and planning, a finished landfill can become a park thus increasing the community assets.

However, the potential danger of ground and surface water pollution by sanitary landfills cannot be overlooked. That is why sanitary landfilling is not the best method everywhere for solid waste disposal.

Land fills must not be located near rivers, canals, lakes, or in areas with high water tables because the leachates will contaminate those water. Leachates are formed when rain, or any form of water, percolate downward through the compacted solid wastes or when water comes into any contact with the wastes. Water, powerful solvent, dissolves organic and inorganic materials and picks up also solid organic and inorganic constituents, i.e. leaches materials out of the wastes. The leachates continue travelling downward or sideways and mix with the ground water. The result is certainly a reduction in the ground water quality, and possibly the creatior of unknown organic compounds.

It is possible sometimes to use plastic or rubber linings to prevent the leachates from contaminating the groundwater.

And in some regions where the proper geologic formations exists, cley can be used to form these linings. But is is difficult, if not impossible, to obtain 100 percent of waterproofing.

The idea of using barriers is to ellect and treat the leachates but many exotic substancos, highly refractory to treatment, may be present and impossible to remove. In areas of high precipitation, the amount of leachte durig the rainy season may be so large that it may overflow into the groundwater unless efforts are made, andat great expense, to collect all the leachate. Because of the high water table in much of South Floride, sanitary landfills should not be used here to dispose of any type of solid wastes.

<u>The Impertance of Shredding.</u> Shredding is a mechanical process which reduces the size of solid wastes, effects higher compaction of wastes, and longthens the life of sanitary landfill. But the advantages of shredding go beyond its application in landfilling. Solid wastes are resources which should not be discarded; and great interest is being expressed in recovery of resources, recyeling, androuse. Shredding is one of the first operations in any resource recovery system.

RECOVERING RESOURCES FROM SOLID WASTES

Basically, there are three forms of resource recovery that municipalities can use today: material conversion, material recycling and energy recovery.

<u>Material Conversion.</u> In this form of resource recovery.

certain wastes are recovered and put to uses which may be vary different from that of the original material. Examples are: making compost out of mixed biogradable materials and using the compost in farming and gardoning: using wasted glas and rubber tires in highway paving; and using flay ash to make construction belocks.

Material Recycling. Recycling means bringing a wasted material back into the process by which it is formed. Examples would be: using wasted paper to make now paper: using bottles thrown away to make new bottles: and using scrap steel to make new steel.

The material being recycled may have different origins: it may be hocm scrap which is material recovered from the mill making it: it may be industrial scrap receivered from plants using the material to manufacture products: and it may be post-consumer, or obsolete scrap, which is the material discorded by the users and which becomes part of the Municipal sold wastes.

Home and industrial scraps are easily recycled because of their purity and short distances from their point of generation. In constrast, most post-consumer scraps are not easily recycled because municipal solid wastes are mixed during the collection.

Envergy Recovery. Under this scheme, energy is recovered as heat. The heat is obtained by buring solid wastes in two different ways: in one, solid wastes are burned together with

a fossil fuel in power plants making electricity. In the second, the solid wastes undergo pyrolysis.

SOME MATERIALS WITH POTENTIAL FOR CONVERSION RECYCLING

Paper, steel, aluminum, and glass are the prime candidates for recovery from municipal solid wastes. Their recovery could contribute substantially to the material needs of the country and would result in great savings of oil and coal.

Paper. Paper constitutes about 35 percent (dry weight) of the municipal solid wastes. In 1973, there were some 45 million tons of paper discarded as post-consumer waste: 8 million tons of discarded newpapers, 10 million tons of corrugated containers. Although paper production and use continues to increase yearly, there is little hope for increased recycling. There are techniques to separate paper from other wastes but separation at the source seems to be the most economical means of removing paper from the waste stream.

Steel. Steel cans account for 7.0 to 8.0 percent (weight) of the municipal solid wastes. Of the 5.5 million tons of steel cans discarded in 1973, 4 million were discarded in Standard Metropolitan Statistical Areas where recovery is more likely to be economically possible.

The technology for recovering steel cans from mixed municipal wastes is well developed and is used in several cities. It consists of a magnetic separator which removes the ferrous

fraction from the wastes. One obestacle to the recovery of steel cans is the aluminum tops in bimcral beverage cans, and its removal raises the cost processing about $ 10 per cent.

Aluminum. In 1973, I million tons of aluminum were discarded and became solid wastes in the United State. About a halfmillion tons were cans, one-third million were aluminum foils, and the rest was aluminum used in mamor appliances. Only 3.5 percent of the discarded aluminum, some 34,000 tons, was recovered. About 78 percent of the aluminum cans were concentrated in five states: Florida, California, New York, Texas, and Washington. The techniques for the mechanical recovery of aluminum cans form municipal solid wastes have not been proven. Much of the aluminum recycled consists of cans recovered manually and brought to collection-recycling centrres operated by the aluminum industry.

Glass. Some 13 million tons of glass products were discarded in 1973. This amounted to 9 percent by weight of the total municipal solid wastes. Only 350,000 tons, less than 3 percent, were recovered and recycled. "Cullet" is scrapglass, usually broken into small, uniform pieces. Clean cullet is an attractive raw material and the demand for it is the same as for virgin material. Color-sorted cullet is preferred over colour-mixed cullet, there being at least twice as many markets for the color-sorted as for the color-mixed class. As all recovered materials, cullet is affected by the presence of contaminants.

by the presence of contaminants.

RECOVERING ENERGY

Besides recyclable materials, solid wastes contain combustible materials such as paper: and plastics. These materials can be used as fuel recovering the chemical energy stored in them as heat. The heat can be used to produce steam that can be used in industrial operations or to produce electricity. The two main processes to recover energy from solid wastes are combustion and pyrolysis. Before discussing these methods, one process involving combustion must be introduced.

Incineration: Combustion can take place without recovering energy. One example is strainght incineration, where solid wastes are burned and changed into gases which are released to the atmosphere. Incineration has been used to reduce the volume of solid wastes out their gascous emissions often violate air quality standards. Since the addition of emission control equipment is very costly, many incinerators have discontinued operations. Straight incineration is wasteful because it does not recover any energy.

Incineration can be used to produce steam for industrial uses. In addition to the environmental problems using 100 percent wastes as a fuel creates other problems, such as the variability in the composition of solid wastes which requires the dissipation of excess heat and provisions for conventional fuel-generated steam in cases of shortages.

Combustion with Heat Recovery. The significant amount of heat produced during the combustion of municipal solid wastes and the increasing cost of conventional fuel, makes the recovery of heat very attractive. While it is not to use a fuel composed of 100 percent wastes, municipal solid wastes can be used as a fuel supplement. This scheme is applicable to electric utilities burning coal to generate electricity.

Using solid wastes as a supplementary fuel in a utility power plant is environmentally and economically attractive. It takes advantage of a combustion system already established; reduces the amount of solid wastes; recovers energy from solid wastes thereby reducing the fuel bill of the utility; permits the recovery and recycle of non-combustible materials such as metals and glass; reduces substantially the cost of municipal wastes disposal; and reduces sources of pollution.

However, there is a major obtacle to the use of solid wastes as a fuel supplement; the only boilers which can accept solid wastes as fuel are those which burn coal. Boilers which at one time burned coal can be retrofitted to burn solid wastes but the conversions costs can be very high.

Pyrolysis: Another energy recovery method of great potential is pyrolysis.

In general, lower temperatures in pyrelysis systems favour the formation of organic liquids while higher temperatures tend to produce gascous products. The organic compounds can be used a fuels and some as sources of chemicals. Another advantage of pyrolysis is that air pollution problems can be

minimized.

CONCLUSIONS

The source of drinking water in much of South Florida is a shallow equifer with a high water table. As such, the water is very sensitive to contamination by dumps and landfills and these methods should not be used for disposal or solid wastes.

Incineration can impet heavily on air quality and wastes the energy present in solid wastes. The increasing cost of energy dictates the recovery of resources from solid wastes. A resource recovery program can include metals, glass and paper.

The combustible fraction of solid wastes can be burned to convert the chemical energy in the wastes into heat. The heat can be used to produce steam and electricity. Unfortunately, the burning of solid waste is feasible in coal-burning boilers or boilers that can be adapted.

The most promosing system of resource recovery in South Florida is pyrolysis. When properly designed and operated, pyrelysis systems permit the recovery of metals, glass, and energy without creating air or water pollution. These are indirect, long-term benefits which, when added to the benefits of proper solid wastes management, have sizeable beneficial effect both environmentally and economically.

SCIENTIFIC ASPECTS OF MUNICIPAL SOLID WASTE MANAGEMENT

- Subhash Dandekar

This paper will discuss briefly the modern and scientific ways in which the waste disposal problem should be dealt with. Refuse production is believed to be increasing now at about 4 per cent per annum. What to do with these sold wastes, how to dispose of them without needlessly endangering public health and welfare and how to recover and reveo valuable materials now' thrown away' are among the most challenging and perplexing of current national problems.

Solid Waste Management deals with refuse collection, storage, transportation of refuse for ultimate disposal sites be applying the principles of Environmental Engineering so that the 'wastes' do not contribute to the Environmental pollution problem. In the light of new technology, solid waste is looked upon as a national resource rather than a nuisance because now the technology is available for recovering and reusing valuable materials from the wastes, using the waste as a road and building material and for generation of steam by bruning it in specially designed incinerators. In Europe such plants are already working satisfactory and a test unit recently installed in Menlo Park, California, U.S.A. has shown promising results. For disposing the solid waste, its physical, chemical and microbiological characteristics should be determined. It is a difficult task firstly because no

Standard methods are laid down, and secondly the characteristics of the waste are function of socio-economic systatus of a particular region geography, climate and season. Nevertheless in order to learn how to manage the nation's daily huge volume of discarded solid waste, people are of necessity beginning to learn something about then in scientific terms.

Physical Characteristics

Knowledge of the physical characteristics of municipal waste is necessary as a basis for developing solid waste storage collection, salvage, disposal facilities and new methods of storage, collection, salvage and disposal.

Municipal solid wastes are classified into two basic categories: to the individual interested in incineration, they are combustible and non-combustible material, to the individual interested in composting and to a lesser degree in sanitary landfill, they are bio-degradable and non-bio-degradable materials. These classifications are, of course too broad to provide scientific information on the possible intrinsic values of a particular solid waste or on the recycling of selected categories.

In general, the following nine categories will provide the incinerator, compost or sanitary landfill engineer with the information needed for disposal plant design:

Food Waste, Garden waste, paper products (plastics, Rubber, Leather), Textiles, Wood, Metals, Glass and Ceramics, (Ash, Rocks, Dirt).

In American Municipal wastes the content of paper is as high as 62 per cent but in our municipal wastes, the paper content will be very low because paper is already pocked up manually at the collection sites which has a resale value.

Chemical Characteristics

The chemical analysis of solid wastes is very involved and complex. No standard methods exist for use in such studies. This lack is further complicated by difficulty in sampling. Ultimate analysis of municipal solid wastes illustrate that there are seven major components, which are Moisture, Carbon, Hydrogen, Oxygen, Nitrogen, Sulphur, Ash and Metal: heat value 3000-6000 BTU/ Ib.

The Sulphur content is extremely low which should make the solid waste a most desirable fuel from the air pollution standpoint, through its variability in BTU and moisture makes it a difficult to work with.

Planning a Collection System

Refuse from the domestic apartments is collected at suitable sites (Municipal Dumps), wherefrom it is picked up by municipal trucks to take it to the disposal sites.

Following factors should be studied and considered to permit adequate planning:

1. Types of refuse produced, volume, weight, compressibility, and method of separation and storage at origin.
2. Number of service steps, quantity of refuse per stop and location of refuse for collection.
3. Type and capacity of collection equipment available or to be selected.
4. Organisation of crews.
5. Topographical feature of the area, street layout, traffic problem.
6. Disposal method or methods.
7. Type of Zoning.
8. Climate.

Disposal Techniques

These days the disposal of solid wastes is carried out in the following ways:

(a) Sanitary land filling;
(b) Composing of Garbage, and
(c) Incineration and then disposing of the ash in land fills.

Sanitary Landfilling

This is a process in which solid waste materials are deposited in cells, crushed and compacted into a dense mass and covered with earth in a carefully controlled sanitary manner. This method is a proven system which when carefully planned and operated is economical and nuisance free.

The filling can be on land ranging from level land to gullees or revines. In many instances, rough and low value land has been improved by filling. Sanitary landfill operation requires careful preliminary evaluation of local conditions.

Factors to be Taken into Considerations

(1) Type of Soil available
(2) Drainage.
(3) Previlling winds.
(4) Availability of access roads.
(5) Possible contamination of ground.
(6) Leakage of gas into the atmosphere and explosion.

How Much Land Required?

It is estimated that 1 acre of land per year will be required per 15,000 population, at a refuse 6 fit. deep.

Three Broad Classification of Operational Techniques

(a) Trench Method,
(b) The area ramp method, and
(c) The area fill method.

Characteristics of the Fill

Chemical, bacteriological and physical changes occur in buried refuse. In about 4 days, at 3 feet below the surface, temperature rises to 130 to 150^{0}F. They remain at this point for 60 days and then gradually fall for about 10 months to near air temperatures. It appears that decomposition proceeds slowly.

Some settlement of the fill should be expected and if the desired elevation of the finished fill is know, allowance for setting can be made during construction. Most of the final settlement will probably occur within the first 12 months and by the end of 2 years, most fills have completed settlement. The amount of settling depends upon: (1) Characteristics of wastes, (2) Compaction given, (3) Depth of the fill.

An ultimate settlement of 10.30 per cent is expected at most fills.

Composting

Compositing is a process in which organic materials are broken down into humus material for use in agriculture, gardening or the improvement of lawns.

Process: Preparation

(1) Removal of Non-Compostables-Metals, Glass, etc.
(2) Grinding or shredding.
(3) Blending or proportioning of materials.
The processing takes place in a compost plant.
Moisture contain should be around 40 to 60 per cent.

Nutrient

Optimum C: N Ratio 30-35: 1 for speedy bacterial action.

A ratio above 35-40: 1 will require a considerable increase in compost time. Blending is considered unnecessary when C:N ratio is 25-50. 1. Blending may be done if loads contain less N_2 (e.g. paper, Straw, Saw dust, etc.) by combining with loads high in N_2 (e.g. wastes from slaughter houses, fish scrap, blood, etc.)

Under normal conditions of bacterial breakdown, humus is produced from waste organic materials such as garbage or agricultural wastes in 6 months to a year. However, if the wastes are finely ground, adjusted to a moisture content to 50-60 per cent and piled in windrows 3' to 4' across the base and 3' to 4' high, a rapid rise in temperature will be observed. If the windrow piles are turned at intervals of 1.2 days, a pleaant smelling humus or campost is produced in about 10 days. During the period, the material will have passed a low P_H or acid stage to high P_H stage.

Process

Oxygen from air penetrates into the voids of the material where it dissoves in the liquid moisture films and is carried on the acrobic bacterial organisms. Large scalo comp osting operation will have to be conducted so that:

(a) The operation is in a thinly inhabited area;

(b) Final drying is carried on in areas separated from

(c) High stacks are utilized for disposing of the mosture vapours, and

(d) Moisture vapours produced are recaptured.

Incineration

Design of incinerator requires expert knowledge in this field or else it will cause a lot of air pollution- principle features are:

1. Charging Apparatus: Mechanical or Automatic.
2. The furnace or Primary chamber (Refractory lined).
3. The combustion or Secondary Chamber.
4. Chimney or stack (Forced draft reduces the Chimney height).

Hand stoked grates will susually burn 40 lb./hr. while the other types will burn up to 70 lb./hr.

Travelling grates are often rated at 300,000 Btu./ (hr.) (sq: ft.) Temperature in the bed of burning refuse may reach 25000 ^{0}F or more. Excess air is required to hold the temperature at 1400-1800 ^{0}F. Above 1800 $0_{F.}$ slag formation may become a problem.

For good incineration, it is necessary to have independent control of the following:

1. Rate of fuel consumption or heat liberation.
2. The composition of the final gas.
3. The flame length which defines the volume in which combustion is taking place.

Sources of Smoke

1. Insufficient Air
2. Excessive Agitation of the fuel bed
3. Volatile matter distilled too far

4. Too small or too cold furnaces
Design could be improved by

1. Furnace Draft Adjustment
2. Type of Stoker
3. Types or combustion control

Advanced Incinerator Concepts

1. Slagging incinerators wherein the residue is metted.
2. Systems using a fluid-bed principle.
3. Systems using the pyrolysis principle.

Pyrolysis appears to be very promising. It is not a waste disposal process but a waste transformation concept. Although some volume reduction is accomplished, the primary effect is to transform a heteroganous, unstable and difficult to handle material into a low Btu gas and liquid steam and a storable oha material.

Salvaging

Whenever possible, recover and rous valuable materials from the waste. This may not be easy and many projects have been undertaken to do it effectively.

SOLID WASTE MANAGEMENT

IN

GREATER BOMBAY

F.A. ATTARWALIA.*

INTRODUCTION:

Solid wastes, like any other wastes, are a result of human activities. With rapid urbanisation, industrialisation, increase in population, increase in standard of living and incssant migration to urban areas, the collection, handling and disposal of solid wastes in metropolitan cities has become a problem of world-wide concern.

Greater Bombay, the most affluent city in India also faceds the mightmare possibility of its teaming millions strangling in their own excrement and garbage. With the georgaphic and demographic growth of the city, the quantity of refuse which was 300 tonnes/day (TPD) a century ago, stands at 3000 TPD to-day. The magnitude of refuse genration can be appreciated by the fact if the annual refuse produced by the city were stored in a sky-scraper of 700 m 2 base area, it would reach to a third of the height of Mt. Everest.

The gigntic task of collection, handling and disposal of solid wastes of Greater Bombay (GB) is rendered by the Cinvervancy Department of the Municipal Corporation of Greater Bombay (GOB) as a unit of the city Engineer's Department and discharges its function as laid down under Section 61 of the Bombay Municipal Corporation Act No. III of 1888, through an organizational set-up of 16,000 persons comprising of verious cadres of supervisory and labour staff.

1. ORGANISATION:

As per the Act, it is incumbebt on the Corporation to make adequate provision by any means of measure which it is lawfully competent to them to use or to take for each of the following:-

1. Seavenging and the removal and disposal of excrementi-tions and other filthy matters and of all ashes, refuse and rubbish.

2. Cleansing of public streets.

In order to adequately render the services broadly outlined above, Greater Bombay is divided into 30 conservancy wards. Each ward is under the control of a Supervisor. The work of three to four supervisors is looked after by an Assistant Head Supervisor (AHS). There are two A.S. Ss in the western suburbs and two in the eastern suburbs and they are responsible to their respective Deputy Head Supervisor are directly responsible to their respective Deputy Head Super-visor are directly responsible to the Head Supervisor (HS). The H.S. assists the Deputy City Engineer, who remains in overall control of the Department and is responsible the city Engineer, Dy. Municipal Commissioner (Zone IV) and the Municipal Commissioner.

Under each Supervisor, there are four to five section Jr. Oversears (JO) and one motor loading J.O. in each shift. Each section J.O. has two mukadams and sixty scavengers.

The section mukadam has about 15 beats. The best area depends on the condition of the a rea- whether congested or sparse, compact or scattered. A beat of two persons- a sweeper and a picker ranges from 3000 to 6000 m^2 for the city area and 6000-10000 m^2 for the suburbs. The beat is swept normally twice and at certain places in the city even three to four times a day. About 6000 scvengers are

employed for this work. Less frequented roads in the interior and in villages are swept once only.

The motor loading work is under the assistant mukadam with six motor loaders who move with a vehicle as per the programme and clean up dumps and sheds. About 4000-5000 motor loading staff is employed. According to the intensity of deposits, clearance is given once / twice a day. / or

II. QUANTITY AND QUALITY OF REFUSE

On an average, about 0.5 kg per persons per day of refuse is generated in G.B. This comes to nearly 3000 TPD. Not all of this refuse is presently collected under the existing conservancy system. In suburbs and extended suburbs, there being open spaces, refuse is many times not collected in receptacles provided for the purpose but is being disposed by the residents in a way prefer. But still about 2500 tonnes of refuse is being collected.

Refuse is of heterogenous nature. It varies from seasons to season and from ward to ward. The standard of living and dietary habits too influence the physical and chemical characteristics of refuse.

Table 1: Gives the characteristics of Refuse of Greater Bombay.

Table 2: gives the chemical characteristics of refuse of GB.

Table 3 : gives the daily tonnage of refuse removed from different wards in peak and lean season.

Table 4: gives the locality-wise characteristies of refuse of GB.

Widespread practice of tatting reflects in the fact that refuse deposited in dust bins or at storage points is not the refuse arriving at dumping grounds.

Table 5: shows the physical analysis of refuse collected from dust bins from 3 sites.

A study of the table reveal that:

1. The higher income group residential areas and commercial areas in Fort show a high peper, metal and plastic content.

2. In general, the refyse has high moisture content even in dry seasons because the city's refuse comes mostly from house gullies in the city and from open drains in the suburbs where it comes into contact with water or sullage. In wet seasons, the refuse is almost drenched.

3. The market areas show a large percentage of garbage, leaves etc.

4. Due to large amount of totting of paper, glass, metal and plastics, their quantities are low in the refuse arriving at dumping grounds.

5. The colorific value is between 4650 KJ / kg to 16350 kj/kg but is generally less than 9300 kj/kg. This does not give a slef-sustaining temperature in the incinerator. Refuse from Fort area is bound to give a higher value and the same is valid for the refuse from hospitals (5).

The industries in Bombay normally have their own arrangement for disposal of industrial wastes. Certain wastes like ash, offal etc. can be disposed directly at the dumping groundswitch the permission of the Corporation.

No detailed chemical analysis of GB refuse is available however, some genral points that can be observed are:

1. The moisture content of refuse from low income areas would be high because of an ill-defined storage place for refuce, which therefore inadvertently gets mixed with sullage water etc.

2. The refuse from market areas due to high organic matter and moisture content purifies rapidly in the climate of the city and therefore should show PH in the acidic range.

3. The refuse has an average compostable portion of 50%.

III. STORAGE AND COLLECTION METHODS:

Different types of bins of metal or concrete and of different shapes- rectangular or circular, are being provided at selected points.

Table 6: shows type and number of receptacles provided in the city and suburbs. The household refuse is either stored in buckets or some type of bins. Standard capacity bins of M.S. according to ISI 1495: 1959 are sometimes provided. Commercial waste is either deposited in the roads debins or simply put on the road by the side of the establishment. Certain industrial and slaughter house wastes come directly to the disposal sites from the source.

The refuse swept from public streets and collected from premises, public bins and dumps is transported in conventional type lorries. The refuse is simple dumped in it and carried to the site. About 250 lorries are used per shift in two shifts of eight hours each. 30% of these vehicles are to the Municipality, the remaining are taken on contract. The former are close -bodied vehicles while the latter are open-bodied. Trailers are also sometimes used. Refuse is transported from Mahalaxmi to Deonar, a distance of 29 km., by railway wagons and two engines are used in two shifts to transport 30% of the refuse per day. At a time, 17 wagons are inadequate Mahalaxmi, 17 are being unloaded at Deonar and the remaining 17 are on the way back to Mahalaxmi.

IV DISPOSAL METHODS:

Land fill method of disposal of garbage in GB has been in vogue prior to the inception of the Bombay Municipal Corporation in 1888. A committee then appointed to study the proposal of disposal of refuse either by incineration or landfill, opted for the latter. A plot of 330 he was therefore acquired, near Chembur at Kurla and Khaji Islands and refuse was transported by train and dumped there. This method still continues and about 205 ha. have already been reclaimed of which about 123 ha are already developed in setting up. housing colonies and Deonar Abattoir- the largest slaughter house in Asia.

With the merger of suburbs and extended suburbs in 1950 and 1957 respectively, the quantity of refuse increased and therefore additional low-laying plots were acquired at Mahim, Malad, Borovili, Andheri, Ghatkopar and Mulund, for disposal by landfill method.

Table 7: gives the details of the various dumping grounds in GB.

Tables 8: gives the amount of daily refuse being dumped at various sites.

At the dumping grounds, use of bulldozer is made for levelling and cimpressing refuse. With an average filling to 2 mtr. about 1.5 ha. are developed per day by dumping 2500 tonnes per day. Non-availability of inert covering material like murram, ash, debris, earth act., Motorable roads on the dumping grounds have decreased the possibility of refuse vehides getting stuck during the monsoon.

A pilot incenerator plant of 10 TPD capacity, with auxillary firing (oil) arrangement and fixed conventional grate, was installed and commissoned in September 1974, to study the feasibility of incinerating city refuse. The entire plant cost about Rs. 2.3 lakhs.

The studies carried out so far in burning market refuse have recealed that even with 30% moisture content in the refuse, continuous oil firing is necessary. Due to the present oil crisis and the high cost of furnace oil, the incineration method is not found to be economical proposition as compared to the existing land-filling method.

V-RESOURCE RECOVERY:

The vast and growing amounts of solid waste generated daily in our cities represents a resource of which no use has been found. Some of the resources available from mixed Municipal solid wastes are shown in Table 9. This means that we must now add such concepts as "refuse of resource materials" and" sequestering of resources" to the traditional definition of solid waste disposal based on either destruction of, or a finality of concern, for the residues of resource exploitation. Thus solid waste disposal no longer implies getting rid of material. It concerns instead how residues of one cycle of use become the building blocks of a new cycle analogous, perhaps to the cycle of biological growth and decay in nature.

Tremandous progress has been made in these lines in U.S.A. and other countries. Various processes for composting have also been developed in India. A review of the literature shows that the conventional systems for resource recovery are mainly two: (i) Heat Recovery Incinerators, and (ii) Mechanical Composting Plants. The former has been developed and used in several countries notably France (7) Germany (8) Switzorland (9) Japan (10) and U.S.A. (11).

These systems are designed to burn mixed municipal wastes and recover the heat energy, usually in for form of steam. The waste is burnt is large furnaces equipped with moving greates. Conventional tube boilers and water-walls convert the heat into steam. In some cases, part or all of the stem is converted into electricity, using conventional steam power plant equipment. As already mentioned, Bombay refuse contains high mosture and is of low calorific value, thus heat recovery incinerators are not an economical proposition.

The production of compost from mixed municipal wastes has been practised -both in India and other countries- since a long time. Compost is useful as a soil conditioner. It improves the structure od clay and other hard soils, and increases moisture holding capacity of soils. The Indian refuse and typically the Bombay refuse is highly amenable to composting because of large organic content. In metropolitan areas, mechanical compositing plants are suitable because they save time and space. Many western processes are available, but an inter-mediate degree of mechanisation will be suitable for pur cities. A project to set up a 300 THO mechanical compost plant is proposed as a Joint venture with the State Government and a private firm for the city of Bombay, Negotiations are in progress with Central and State Governments for finance and for assurance for sale and distribution of compost ex-plant.

Many advanced processes like the Black Clauson com (12) and the U.S. Bureau of Mines (13) for material recovery, the Horner Shifrin System (14) the American theremogen, Meltzit Incierarot (15) and the CPO-400 of the Combustion power Co. (16) for energy recovery, pyrolysis systems of Garret Research and Development Co. (17) Monsanto's Enviro-hem (18) and Harcules Inc. (19) for obtaining oil or gas, and other chemical convarsion systems which convert the cellulosic portion of the waste by ohydrolysis (2) hydrogenation (21), wat oxidation (22-23), photo-degretion and anserobic digestion(24, 25, 26,) into usable products have been developed.

Some of this processes are in conceptual stage, some have been tested in laboratory equipments, while some have been tested on pilot plants. Recently pyrolysis units have benput up on commercial stream. Until the viability of these systms are proved, their implementation has to be cautious.

VI ECONOMICS:

For the removal of 2500 tonnes of refuse daily the MCGB spends about Rs. 7 crores annually. This comes to about Rs. 9.50 per capita and about Rs. 82/- per tonne. Approximate break-up of this rat is as follows:-

Collection charges........................	Rs. 35/-	per tonne.
Transportation including loading & unloading........................	Rs. 45/-	" "
Disposal..................................	Rs. 3/-	" "
Total	Rs. 83/-	" "

If the refuse if disposed by incineration, without involving the element of collection and transportation, the cost calculated for the 10 TPD pilot plant works out the as Rs. 90/- to Rs. 120/- per tonne. Typical costs for sanitary land-filling are Rs. 42/- pertonne (See Fig. 4 and Appendix B) and Composting are Rs. 60/- to Rs. 70/- per tonne.

Materials Recovery is unsuitable for Bombay refuse because of low contents of plastic, paper and matals. Pyrolysis of solid wastes seems an attractive altarnative for disposal of sllid wastes and further work on Bombay refuse is required to prove its economic viability.

[illegible] SOCIO- ECONOMIC PROBLEMS:

(1) Litter.

The potential sources of litter are:

(i) Areas near refuse bins visited by pickers or stray animals.
(ii) Inconsiderate throwing of sweepings from commercial estabilishments when they open in the morning.
(iii) Hawkers and Vendors.
(iv) Bus stops and Bus' Chukies:
(v) House gullies and open chouks.
(vi) pedstrians habits.

At least to minise the magnitude of the problem due to latter, strong legislation and effective enforcement is required.

(2) Civic Sence & Education

The problems of Solid Waste Management, therefore, are of two types- the technical problems and socio-economic problems. With existing technology, management of solid waste activities by trained engineers would solve the first problem. But to keep the environment clean requires not only the solution of technical problems but also the public acceptance, co-operation and participation. After all, every individual contributes his mite to generation of solid waste, but he should also be disciplined so as not to pollute his environment. To do this, educational techniques and media like posters, publicity leaflects, films and cinema slides should be prepared emphasising various aspects of keeping the enviorment clean. Services of leading cartoonist should be enlisted for the purpose. Educational leaflects should be distributed to householders, to techers and children in school, and to those at their places of work. Talks, lectures and films shows may be given in clubs, youth organisations, school and community centres by both experts and well informed laymen, and articles in the press ---

and radio and T.V. programmes may also be used to impart information and stimulate thinking and discussion. The detailed operation of the solid waste education programme should be handled by the professional and technical staff of the sanitation department and in particularal by the Solid Waste Management Section.

VII- CONCLUSION

In this brief study of Solid Waste Management, the areas where there is a scope for improvement are pointed out. Unless there is whole-hearted participation and support of every citizen, who realises his social responsibilities, no effective solution can be found to tackle the solid waste problem. The importance of proper education programmes and campaigns for clean cities together with bold legislation and effective implementation of this legislation, needs no emphasis.

IX- REFERENCES

1. Phadke, N.S.,Thakur, S.G. at al. 'Character and Problems of Disposal of Wastes from Large Cities', Paper presented at Seminar on Solid in Metropolitan Area, held in Bombay, 1975.

2. Rotakar, B.V., at al. 'Magnitude of Solid Waste Problem of the Bombay Metropolitan, Op. cit (1).
3. Phadke, N.S. Op.cit. (1).
4. Attrualla , F.A. op. cit. (1).
5. Phadke, N.S., op. cit (1).
6. Attarwalla, F.A. op. cit. (4).

7. Raussoau, H., 'Large Plants for Incineration of Refuse in the paris Metropolitan A rea ' 1968. National Incinerator Conference (ASME).

8. Anon, 'Power from Refuse'. Mechanical Engineering, March, 1978.

9. Ane, 'Solid Waste Disposal in Switzerland'- 4th International Congress of the International Group on Refuse Disposal, Bansel, Switerzerland, June 2-5, 1969.

10. Matsumoto, K, et. al' The Practice of Reguse Incineration in Japan' 1968. National Incinerter Conference (ASME), 1968.

11. Anco, 'Northwest Incinerator Plant'. Solid Waste Management, May 1971.

12. Herbet, W. 'Solid Waste Recyclng at Franklin, Ohio: proceedings of the Third Mineral Waste Utilization Symposium March 14-16, 1972.

13. Horen, J.H., Peter, F.A. 'Cost Evaluation of a Metal and Mineral Recovery, Process for Treating Municipal Incinerator Residues', US bureau of Mines Information Circular, No. 8533, 1971.

14. Horner and Shifrin, Consulting Engineers, 'Appraisal of use of Solid Waste as Supplementary Fuel in Power Plant Fuel's, St. Lou, Missouri, Feb. 1973.

15. American Thermogen, Inc, 'Utra High Temperature Total Reduction of Municipal Solid Wastes'. Whitman, Mass., July, 1971.

16. Bergio, J.J. et at. 'A progress Report on the CPV -400 Project'. PHSP. OSWMP, EPA, 1970.

17. Mallan, G.M. 'A Total Recovery Process for Municipal Solid Wastes ' Presented at 161 st ACS National Meeting, L. A. California, 31 st March, 1971.

18. Stephenson, J.W., 'Some Recent Developments in Disposal of Solid Wastes by High Temperature Combustion Pyrolysis and Fluid Bed Reactor' presented to N.Y. State Action for Clean Air Committee, May, 7, 1971.

19. Hercules, Inc. 'The Hercules Solid Waste Reclamation Concep t' 16 Aug. 1971.

20. Anon, 'Construction of Clifornia, 'Comprehensive Studies of Solid Waste Management'-2nd Annual Report, Serl. No. 69-1, Jan. 1969.

21. University of California, 'Comprehensive Studies of Solid Waste Management'. - 2 nd Annual Report, Serl. No. 69-1, Jan, 1969.

22. Anon. 'Pyrolysis, Hydrogenation and Incineration of Municipal Refuse- A Progress Report. Prec. of 2nd Mineral Utilization Symposium, Chicago, March 1970.

23. University of Cali fornia, 'Comprehensive Studies of Solid Waste Management. 3rd Annual Report, Serl. No. 70 - 2 , 1970.

24. Op. cit. (21).

25. Hoffman, D.A. Fitz, R.A.
(Batch Report Pyrolysis for Solid Municipal Refuse' Environment Science and Technology, Vol, 2. No. 11, Nov. 1968, p. 1023.

26. Anon, Solid Waste Report, Vol. 2, No. 4 Feb. 1971.

TABLE- 1

PHYSICAL CHARACTERISTICS OF REFUSE OF GREATER BOMBAY
(EXPRESSED IN % BY WEIGHT OF REFUSE EXCEPT BULK DENSITY)

Constituents	Average Values
Paper, Newspaper, Hardboard.	2.40 .
Wood Chipe/wood.	4.57 .
Baggase.	0.90 .
Plastics.	4.00 .
Straw, Dry Leves,	6.60 .
Coconut Snelle, Fihres.	1.20 .
Coal.	8.6 .
Bag's, Textiles	2.16 .
Garbage**	0.07 .
Leather.	1.68 .
Bencs, Egg Shells Etc.	2.10 .
Rubber	0.90 .
Inert Matter	6.80 .
Glass.	0.57 .
Motals.	0.26 .
Moisture Content.	580.17 .
Bulk Density.	207.33 Kg/m^3

* The figures given in this table are based on analysis of refuse samples collected from trucks reaching Dharevi Dumping Ground.

** Garbage includes Food waste, fruits, Vegetables, Flowers etc.

*** Item not included in above listed constitutions.

TABLE- 2

CHEMICAL ANALYSIS OF REFUSE OF GREATER BOMBAY (2)
(Expressed as % on dry weight basis)

Item	Percentage
O	31.40
N (as N_2O)	0.754
P (as P_2O_5)	0.584
K (as K_2O)	0.798

TABLE- 6

TYPE AND NUMBER OF REFUSE RECEPTACLES IN G.B.

Type	Number	
	City	Suburbs
Sheds.	92	10
Refuse Trailors.	18	-
Refuse Bins:		
Rectangular.	430	2035
Masonry.	44	617
Tilting.	102	62

TABLE- 3

TOTAL TONNAGE OF REMOVED DAILY WARDWISE IN GB.

Ward	Area in Sq. Kms.	Population	total Tonnage of (April-Peak Oct.) Season. June 1975)	refuse removed Loan Season (Nov., March (Jan. 1976)
A	11.41	1,84,104	205	182
B	2.46	1,75,131	165	1137
C	1.78	3,12,472	245	210
D	6.63	33,82,742	335	279
E	7.41	5,28,736	315	309
F	21.17	6,62,516	275	247
G	17.85	8,24,677	380	237
H	21.05	5,23,633	195	159
K	47.46	5,73,693	185	96
L	13.46	2,73,507	80	58
M	54.92	3,16,371	90	85
N	55.44	4,79,660	80	74
P	64.27	3,72,325	130	102
R	77.56	2,35,833	90	73
T	34.84	1,25,165	55	64

TABLE- 4

LOCALITY- WISE CHARACTER OF REFUSE (BY WT. * OF GREATER BOMBAY (3)

Area	Compostible ** Matter	Combustible *** Matter	Inert Organic Matter	Metal	Moisture
Residental High Income Group	56.06	28.79	13.28	1.87	56.6
Residential Middle Income Group	36.37	43.47	18.05	2.11	42.4
Residential Mixed Income Group	43.67	42.17	10.40	3.36	53.7
Commercial Area	40.69	36.51	22.48	0.32	43.6
Market Waste: Vegetable Market-	63.00	27.30	4.93	4.77	53.3
Meat Market-	62.00	38.00	-	-	71.0
Hospital Waste	53.63	45.66	0.71	-	69.0

* Percentage of wet wt. of refuse.

** Fruit, Flower, food waste etc. of refuse.

*** paper, wood, bagasse, Plastics etc.

TABLE- 5

ANALYSIS OF REFUSE COLLECTED FROM DUST BINS FROM % SITES (4)

Locality	Fine dust & cinder 1.5 cm.	Cinder conetent (1.5-4.0 cm.)	Garbage	Paper	Metal	Rags	Glass	Plastic
Ashok Apart-ments Napean Sea Road	22.59	1.60	16.99	5.56	11.42	0.60	1.57	20.67
A/North Ward.	15.32	0.61	37.92	16.31	0.87	2.17	0.96	4.56
Dadar, G3, G4 Wards	6.07	0.96	45.50	6.23	2.24	4.50	2.15	11.25

TABLE -7

DETAILS OF REFUSE DUMPING GROUNDS IN GREATER BOMBAY (6)

Name	Ownership	Year since used	Total area in ha	Area so far filled up in ha	Whether in use or abandoned.	Planned useage of the Develops Land
Deonar-Borla	Municipal	1897	330	200	In use	For housing and Industries
Mtiwara-Batshuri	Municipal	1940	2.8	2.8	Closed in 1972	For garden, Scho & Maternity Home
Chatkopar Deoali	Municipal	1950	2.0	2	Closed in 1965	For Industrial Est
Dharavi-Mahimi	Collector	1957	-	8	In use	Goods Terminus and Terminus
Glatokoper Estate	Municipal	1968	2.0	2	Closed in 1971	Pumping Station
Mulund Octroi Naka	Municipal	1968	32.8	2.4	In use	- - - - - - - -
Chincholi	Municipal	1970	5.6	2.4	In use	For dog Kennel and Garden
Gorai	Municipal	1970	8.0	1.6	In use	For Industries.

QUANTITY OF REFUSE DEMPED AT VARIOUS DUMPING GROUNDS

Place	Quantity
Dharavi	1550 Tonnes .
Deonar	600 Tonnes .
Malad	250 Tonnes .
Borivli	50 Tonnes .
TOTAL:	2500 TONNES .

TABLE (9)

TYPICAL RESOURCES AVAILABLE FROM MUNICIPAL REFUSE

RECYCLABLE MATERIALS	RECLAIMED MATERIALS
Paper	Heat
Plastics.	Electricity
Forrous Metals	Compost.
Non-ferrous metals	Fuel
Glass	Tar
Miscellenous materials.	Char
	Protein
	Methane
	Glucose
	Yeast
	Other organics.